Lecture Notes in Computer Science 1370

Norbert A. Streitz Shin'ichi Konomi
Heinz-Jürgen Burkhardt (Eds.)

Cooperative Buildings

Integrating Information, Organization, and Architecture

First International Workshop, CoBuild'98
Darmstadt, Germany, February 1998
Proceedings

Springer

Lecture Notes in Computer Science 1370
Edited by G. Goos, J. Hartmanis and J. van Leeuwen

Springer
Berlin
Heidelberg
New York
Barcelona
Budapest
Hong Kong
London
Milan
Paris
Santa Clara
Singapore
Tokyo

Norbert A. Streitz   Shin'ichi Konomi
Heinz-Jürgen Burkhardt (Eds.)

Cooperative Buildings

Integrating Information, Organization, and Architecture

First International Workshop, CoBuild'98
Darmstadt, Germany, February 25-26, 1998
Proceedings

Springer

Series Editors

Gerhard Goos, Karlsruhe University, Germany
Juris Hartmanis, Cornell University, NY, USA
Jan van Leeuwen, Utrecht University, The Netherlands

Volume Editors

Norbert A. Streitz
Shin'ichi Konomi
GMD - German National Research Center for Information Technology
IPSI - Integrated Pubication and Information Systems Institute
Dolivostr. 15, D-64293 Darmstadt, Germany
E-mail: {streitz/konomi}@darmstadt.gmd.de

Heinz-Jürgen Burkhardt
GMD - German National Research Center for Information Technology
TKT - Institute for Telecooperation Technology
Rheinstr. 75, D-64295 Darmstadt, Germany
E-mail: burkhardt@darmstadt.gmd.de

Cataloging-in-Publication data applied for

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Cooperative buildings : integrating information, organization, and architecture ; first international workshop ; proceedings / CoBuild '98, Darmstadt, Germany, February 1998 / Norbert A. Streitz . . . (ed.). - Berlin ; Heidelberg ; New York ; Barcelona ; Budapest ; Hong Kong ; London ; Milan ; Paris ; Santa Clara ; Singapore ; Tokyo : Springer, 1998
(Lecture notes in computer science ; Vol. 1370)
ISBN 3-540-64237-4

CR Subject Classification (1991): B.4, C.3, H.1.2, H.4, H.5, J.4, K.4, K.6, J.7

ISSN 0302-9743
ISBN 3-540-64237-4 Springer-Verlag Berlin Heidelberg New York

Typesetting: Camera-ready by author
SPIN 10631887 06/3142 – 5 4 3 2 1 0 Printed on acid-free paper

Preface

This volume constitutes the proceedings of the First International Workshop on Cooperative Buildings (CoBuild'98) – Integrating Information, Organization, and Architecture, held in Darmstadt, Germany, on February 25–26, 1998. The idea for this workshop and actually the term "cooperative building" was created during the activities of initiating the consortium "Workspaces of the Future" for conducting an interdisciplinary R&D program in cooperation with partners from industry. We discovered that there was no appropriate forum to present research at the intersection of information technology, organizational innovation, and architecture.

The theme "Integrating information, organization, and architecture" reflects the challenges resulting from current and future developments in these three areas. In the future, work and cooperation in organizations will be characterized by a degree of dynamics, flexibility, and mobility that will go far beyond many of today's developments and examples. The introduction of information and communication technology has already changed processes and contents of work significantly. However, the design of work environments, especially physical work spaces as offices and buildings, remained almost unchanged. It is time to reflect these developments in the design of equally dynamic, flexible, and mobile work environments. The papers of this volume show that this is an interdisciplinary endeavor requiring a wide range of perspectives and the utilization of results from various areas of research and practice.

The workshop was organized by the German National Research Center for Information Technology, in particular by the two research institutes in Darmstadt, Integrated Publication and Information Systems Institute (IPSI) and the Institute for Telecooperation Technology (TKT), in the context of their joint effort organizing the R&D consortium "Workspaces of the Future". The workshop was held in cooperation with the following scientific societies: Gesellschaft für Informatik (GI), European Association of Cognitive Ergonomics (EACE), and the Association of Computing Machinery (ACM).

The technical program of CoBuild'98 presented in this volume is the result of the review and selection process of the international program committee. From the submitted papers, we selected 22 high quality papers: 18 to be presented as full papers and 4 as short papers. The selected papers were complemented by two invited speakers. Due to the very interdisciplinary nature of the workshop, the papers cover a wide range of topics. They therefore had to be reviewed from multiple perspectives which was not always an easy task. I would like to express my sincere thanks to the members of the program committee for their careful reviews and constructive comments which often helped to improve the final versions of the papers.

Finally, I would like to express my sincere thanks to Shin'ichi Konomi for compiling and copy-editing the camera-ready manuscript and for creating the workshop's website. I extend special thanks to Hans-Jürgen Burkhardt, the conference co-chair, and to Knut Bahr and the members of the organization committee for their effort in taking care of all those additional issues that are essential for a successful workshop.

Darmstadt, January 1998 Norbert A. Streitz (Program Chair)

Supporting/Cooperating Societies

Gesellschaft für Informatik (GI) mit den Fachgruppen:

- 2.3.1 Software Ergonomie
- 4.9.1 Hypertext-/mediasysteme
- 5.5.1 CSCW in Organisationen

European Association of Cognitive Ergonomics (EACE)

Association for Computing Machinery (ACM) with the special interest groups:

- SIGCHI (Computer-Human Interaction)
- SIGGROUP (Group Work, CSCW)
- SIGLINK (Hypertext, Hypermedia)
- SIGMM (Multimedia)

Conference Committee

Conference Chairs

Heinz-Jürgen Burkhardt	GMD-TKT, Darmstadt
Norbert A. Streitz	GMD-IPSI, Darmstadt

Program Committee

Norbert A. Streitz (Chair)	GMD-IPSI, Darmstadt
Roy Ascott	University of Wales College, Newport
Knut Bahr	GMD-TKT, Darmstadt
Hans-Jörg Bullinger	FhG-IAO, Stuttgart
Heinz-Jürgen Burkhardt	GMD-TKT, Darmstadt
Ernest Edmonds	University of Loughborough
Kay Friedrichs	Netz@Werk FM, Aachen
Wilhelm Glaser	University of Tübingen
Volker Hartkopf	Carnegie Mellon University, Pittsburgh
Ludger Hovestadt	University of Kaiserslautern
Hiroshi Ishii	MIT MediaLab, Cambridge
Niklaus Kohler	ifib, University of Karlsruhe
Christel Kumbruck	provet, Kassel
Saadi Lahlou	Electricité de France, Paris
Gale Moore	University of Toronto
Tom Moran	Xerox PARC, Palo Alto
William Mitchell	MIT School of Architecture, Cambridge
Steven Poltrock	Boeing Company, Seattle
Ralf Reichwald	Technical University München
Jun Rekimoto	SONY Computer Science Lab, Tokyo
Ken Sakamura	University of Tokyo
Gerhard Schmitt	ETH Zürich
Jean Schweitzer	Siemens, Saarbrücken
Ralf Steinmetz	GMD-IPSI & Darmstadt University of Technology
Heinz Thielmann	GMD-TKT, Darmstadt

Publication and Website

Shin'ichi Konomi	GMD-IPSI, Darmstadt
Norbert A. Streitz	GMD-IPSI, Darmstadt

Organization Committee

Knut Bahr	GMD-TKT, Darmstadt
Michael Baukloh	GMD-TKT, Darmstadt
Heinz-Jürgen Burkhardt	GMD-TKT, Darmstadt
Christian Müller-Tomfelde	GMD-IPSI, Darmstadt
Rolf Reinema	GMD-TKT, Darmstadt
Norbert A. Streitz	GMD-IPSI, Darmstadt

Table of Contents

Virtual Environments and Software Technologies

Evolutionary Design of Buildings

Visions and Legislation

Opening Keynote Speech

The Invisible Interface: Increasing the Power of the Environment through Calm Technology

Mark Weiser

Xerox Palo Alto Research Center (PARC)
Palo Alto, CA 94304, USA
Email: weiser@parc.xerox.com

Dr. Mark Weiser is the Chief Technologist at the Xerox Palo Alto Research Center (PARC). Weiser has no bachelor's degree; his PhD is in Computer and Communications Sciences from the University of Michigan (1979). Weiser was assistant and associate professor and associate chair in the Computer Science Department at the University of Maryland from 1979 to 1987, when he joined Xerox PARC as member of the technical staff, then heading the Computer Science Laboratory for seven years. He has started three companies. His over 75 technical publications are on such areas as the psychology of programming, program slicing, operating systems, programming environments, garbage collection, and technological ethics. Weiser's work since 1988 has been focused on Ubiquitous Computing, a program he initiated that envisions PC's being replaced with invisible computers embedded in everyday objects. He believes that this will lead to an era of "calm technology", in which technology, rather than panicking us, helps us focus on what is really important to us. Weiser is also the drummer of the rock band Severe Tire Damage, the first live band on the Internet.

Closing Keynote Speech

Working Place for the Knowledge Economy

John Worthington

DEGW International Consultants on
Workplace Programming, Planning and Management
8 Crinan Street, London N1 9SQ, UK
and
Department of Architecture, University of Sheffield, UK

Email: jworthington@degw.co.uk

The organisation and location of work has changed dramatically in the last decade, reflecting the accumulation of Information and Communication Technology (ICT) by businesses in a quest to improve performance. Technology since the introduction of the IBM PC in 1980 has become more powerful, mobile, wireless and networked. In the 1980's the effect on the building environment was to take space, create heat, proliferate units and place demands on the specification of the building shell. Many of these constraints have evaporated as we near the end of the 1990's. The role of information technology has become absorbed and ubiquitous . The impact today is on location, settings and the new paradigms which have emerged of work.

The impact on work and the work place is that work can and is done anywhere at any time. The office is the place of face to face exchange with less emphasis on ownership of personal space, and a greater focus on meetings, team work and "transaction". Space and time utilisation studies of a professional organisation show that on average staff members may only be in the office 60% of their working day and of that time only spend 40% at their personal workspace. Compound these figures with the calculation that of all the hours available in a year the office is only on average used for 10-15% of that time, and we recognise an increasingly valuable resource which is dramatically underutilised. DEGW's analysis of working practices and time utilisation for a number of major organisations have moved us to "new ways of working" where space is shared, a wider and more appropriate range of work settings is created, and the technology is mobile. The result is a shift from the office as a factory to the transactional office of the "club", "hive" and cell.

As the office becomes the meeting point, new locations are emerging. Points of attraction are going to be multi-functional, sixteen hour usage, accessible by both public and private transport and with a distinctive personality. The presentation will describe Utrecht in the Randstadt (Netherlands) as one of the emerging modes. A high intensity of working, living and commercial functions are planned related to a station with over 45 million passengers per year, which with the fact rail will be 22 minutes from

Schiphol airport and is adjacent to world quality exhibition grounds, and a historical core. The presentation will describe the planned characteristics of such a location, the proposed building types, and the mix of users and their resultant work settings.

John Worthington is the Deputy Chairman of DEGW: International consultants on workplace programming, planning and management. He is a visiting professor on Briefing and Building Performance at the Department of Architecture, University of Sheffield. From 1992 – 1997, he was a Professor of Architecture and Director of the Institute of Advanced Architectural Studies (IoAAS) the University of York.

John Worthington addresses public authority, private developers and multi national corporations across Europe on briefing for the more efficient use and development of urban areas, buildings and settings. He was director responsible for the multi client study on *Intelligent Buildings in Europe (1991)* and has recently *published Reinventing the Workplace (Butterworths 1997).*

Roomware for Cooperative Buildings: Integrated Design of Architectural Spaces and Information Spaces

Norbert A. Streitz, Jörg Geißler, Torsten Holmer

GMD - German National Research Center for Information Technology
IPSI - Integrated Publication and Information Systems Institute

GMD-IPSI, Dolivostr. 15, D-64293 Darmstadt, Germany
Email: [streitz, geissler, holmer]@darmstadt.gmd.de

Abstract. In this paper, we introduce the concepts of "cooperative buildings" and "roomware" and place them in the context of the integrated design of real, physical, resp. architectural spaces and virtual, resp. digital information spaces. By "roomware" we mean computer-augmented things in rooms, like doors, walls, furniture, and others. The general approach is detailed via examples from the i-LAND project where we develop several "roomware" components in order to realize an interactive information and cooperation landscape, e.g. an innovative work environment for creativity teams. We describe the current realization of i-LAND which includes an interactive electronic wall, an interactive table, computer-augmented chairs, and a mechanism for assigning physical objects as representatives of information objects in the virtual world.

Keywords. cooperative buildings, shared workspaces, physical space, architecture, virtual world, information space, augmented reality, roomware, furniture, dynamic offices, team work, creativity support, CSCW, human-computer interaction.

1 Introduction

Introducing information and communication technology already changed work processes and the content of work significantly. However, the design of work environments, especially physical work spaces such as offices and buildings, remained almost unchanged. Neither new forms of organizations nor computer-supported work practices have been reflected in relevant and sufficient depth in the design of office space and building structures. In the future, work and cooperation in organizations will be characterized by a degree of dynamics, flexibility, and mobility that will go far beyond many of today's developments and examples. On demand and ad hoc formation of teams, virtual organizations, physically distributed and mobile workers are only initial examples of the work practices and organizational innovation to be expected. Contents and participants as well as contexts, tasks, processes and structures of collaboration will be changing frequently, in various ways and with an increasing rate of the innovation cycle. It is time to reflect these developments in the design of equally dynamic, flexible, and mobile work environments.

The paper is organized as follows. First, we introduce the concept of a "cooperative building" and describe three dimensions relevant for determining the scope of this concept. Second, we focus on the integrated design of the physical space and related information spaces. This includes the introduction of the "roomware" concept and the so-called A^3-environments based on the requirements derived from three sample scenarios. The main part of the paper is then devoted to the i-LAND project and the presentation of the roomware components we have developed. Finally, we put our work in perspective to related work and close with comments on future work.

2 Cooperative Buildings

We propose the concept of a *cooperative building* as a flexible and dynamic environment that provides cooperative workspaces supporting and augmenting human communication and collaboration. By the choice of this term we want to indicate that the building serves the purpose of cooperation and, at the same time, it is also "cooperative" towards its inhabitants and visitors. This is to say that the building does not only provide facilities but it can also (re)act "on its own" after having identified certain conditions. According to our vision, it will diagnose problems, provide information, establish connections between people, and offer "help". It will adapt to changing situations and provide context-sensitive information according to knowledge about past and current states or actions and, if available, about plans of the people.

While the term "building" implies strong associations with a physical structure, our concept of a cooperative building goes beyond this. It is our understanding that a cooperative building originates in the physical architectural space but it is complemented by components realized as objects and structures in virtual information spaces. Combining real and virtual worlds in a computer-augmented environment allows us to design enabling interfaces that build on the best affordances of everyday reality and virtuality. As designers of human-computer interaction or rather human-information interaction and human-human cooperation, we seek to use the best aspects of each. This perspective is inspired by related approaches in augmented reality (Wellner *et al.*, 1993), ubiquitous computing (Weiser, 1991), tangible bits and ambient media (Ishii & Ullmer, 1997) described in the related work section. We will provide examples of our realizations, e.g., in the i-LAND project in subsequent sections.

A related aspect is that a cooperative building is not restricted to one physical location. Our perspective encompasses a distributed setting with remote locations where people work and dwell. The remote location might be an office building at another site of the organization or in a building at a client's site, a teleworker's small office at home or the temporary hotel room of a salesperson "on the road". Within the framework of a cooperative building, people can communicate, share information and work cooperatively independent of the physical location. In contrast to today's restricted desktop-based videoconferencing scenarios, we envision a seamless integration of information and communication technology in the respective local environment. This results in more transparency and a direct and intuitive way of interaction, communication and cooperation in distributed environments. This approach builds on our earlier work on ubiquitous collaboration (Streitz, 1996) and is in line with the work on media spaces (Bly *et al.*, 1993) and ubiquitous media (Buxton, 1997).

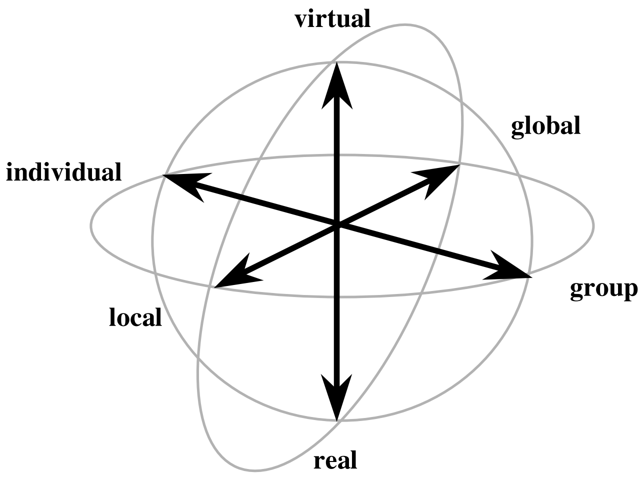


Fig. 1. Three dimensions of cooperative buildings.

For our thinking it was useful to distinguish the three dimensions shown in Fig.1. While each of these have been addressed before, the integrated global picture has still to be constructed. A central aspect is the *"real vs. virtual world" dimension* or, using a different terminology, the physical or architectural space vs. the digital information space or cyberspace. While each terminology has its own set of connotations, we will use them here more or less interchangeable. Our day-to-day living and working environment is highly determined by the physical, architectural space around us constituted by buildings with walls, floors, ceilings, furniture, etc. They constitute also rich information spaces due to the inherent affordances either as direct information sources (e.g., calendars, maps, charts hanging on the walls, books and memos lying on the desks), or by providing ambient peripheral information (e.g., sounds of people passing by). With the advent of information technology the situation changed dramatically. Information is a resource that is more and more available via the computer, usually the desktop computer. People tend to view information now as primarily available by "diving" into cyberspace. The situation changed not only in terms of having a different "place" or "location" for, in principle, the "same" information (e.g., on-line calendars, e-mail, electronic documents, on-line data bases) but - more important - in terms of new categories, constellations and ways of presenting information. Some of it has no counterpart anymore in the real physical world as, e.g., artificial worlds, virtual reality. Furthermore, in many cases it will be updated more often than other sources of information.

There is another aspect of the "virtual" part of this dimension. It refers to the situation where people are not in one physical location but in remote, distributed locations. Associated terms are virtual meetings, virtual teams, virtual organizations, but one has to note that the people, for example, of a virtual team, participating in a so-called virtual meeting are still real people[1] in real physical spaces. If one goes beyond standard desktop video conferencing, one is faced with challenging design issues for creating a "shared" background setting in which the distributed members are placed (Buxton, 1997).

This interpretation of "virtual" is, of course, closely related to the *"local vs. global context" dimension*. This dimension addresses the issue that we have to design the local environment with respect to the requirements resulting from its two roles. One role is to augment individual work and support group work in face-to-face meetings. The other is to provide an environment that facilitates the global cooperation of distributed people. While there is an intuitive understanding of the meaning of "local" vs. global", one has to look at it in more detail. The term "local" is often used synonymous with co-located or "same place". Think for example of a standard office or meeting room. But what is the scope of the "same place" ? Is the hallway part of it when the door is open ? Where are the boundaries " ? In contrast, where does a "remote" place begin ? Is the meeting room on the next floor local because it is "near by" or a remote place ? Does the notion of remote location and global context start in another building, another city or another continent ? In the i-LAND project, we will use sensors for determining positions. Thus, the information devices know where they are, what their local and global context is, and the cooperative building can be provided with information about the location of people in relationship to the devices.

In i-LAND, we currently concentrate on the design of "near by" local environments, i.e. within one building, but we keep in mind that they will also serve as local counterparts for global cooperation. Each venue of a global distributed cooperation scenario has to offer much more than the current individual desktop office. This implies that one has to look "beyond desktops" when designing this type of support.

A third relevant distinction is based on the *"individual vs. group" dimension*. It emphasizes that the type of support should be able to distinguish, for example, between different degrees of coupling shared workspaces. This is based on our earlier work on cooperative hypermedia systems (Streitz, 1996). It should be possible to determine the degree of coupling by the users and provide awareness about who is sharing what and to which degree. This dimension reflects also the implications of different phases of team work: plenary presentation and discussion in the complete group, splitting up in subgroups, working individually on an assigned task, resuming again for the integration of ideas and merging of intermediary results, etc. At a more general level, this dimension addresses the differences in social contexts of work arising from different organizational structures.

In summary, it is our opinion that the realization of a "cooperative building" has to pay attention to these three dimensions in order to constitute the basis for designing, using, and evaluating the Workspaces of the Future.

---

[1] There is no space to address the concept of avatars here. They certainly have interesting implications for the issues discussed here.

3 Integrated Design of Architectural Space and Information Space

In our current work, we concentrate on two of the three dimensions discussed in the previous section: the real vs. virtual and the individual vs. group dimension.

In order to develop a cooperative building or parts of it, we follow a human-centered design approach. The human is at the center of our considerations. However, the human is part of a group or a team and the team has to be viewed in the context of an organization. Combining this with the previous goal of an integrated design of the physical space and the information space, we arrive at the following four spaces (Fig. 2) which need to be addressed in the overall design:

The *cognitive space* of the individual processing content in order to solve the tasks, the *social space* reflecting work practices and organizational context, the *physical space* including the architectural components of the building and the roomware, and the *information space* provided and mediated by networked information devices providing the functionality needed for working on the task.

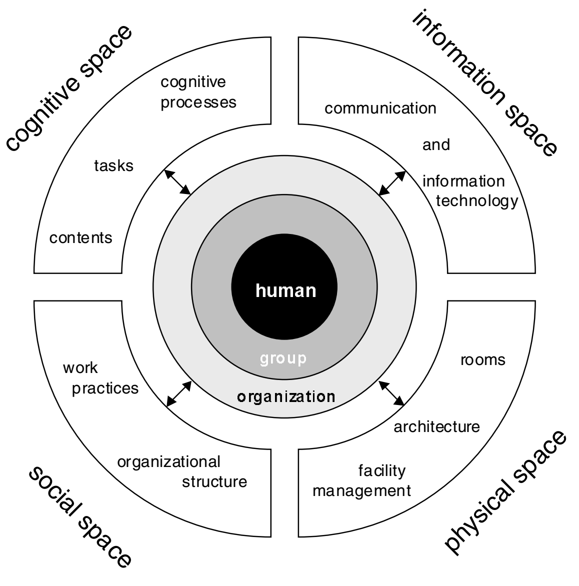


Fig. 2. Design spaces of cooperative buildings.

Our design of the cooperative workspaces provided by a cooperative building is driven by example application scenarios but we are not limited to them. In the following, we describe scenarios, derive requirements and present proposals for design.

It is our vision of the workspaces of the future that *the world around us is the interface to information* (re)presented via ubiquitous devices, some of them visible, others "invisible" in the sense that they are embedded in the physical environment. We anticipate a situation, where we do not have to go to a specific place (e.g., the desktop computer in an assigned office) to interact with information and where people interact with each other mediated by digital information. Instead, ubiquitous and interactive landscapes for interaction and cooperation augment our reality.

3.1 The *Roomware* Concept

Inspired by previous work on augmented reality and ubiquitous computing and our own work on electronic meeting rooms, we describe now two application scenarios which served as starting points for our roomware concept.

Scenario One: A meeting in the hallway. Meeting a colleague by chance in the hallway and starting a discussion might result in the intention to explain something by drawing a sketch on the wall and annotate it by scribbles. Besides the fact that this is usually not accepted in our office buildings, in current buildings with existing technology one could not store and later modify these elements of the discussion. It is also not possible to search for related information in a background information base and to link this information to the sketch and the scribbles on the wall. When the two are finished, the result of the work should disappear from the wall but still be accessible at any other place in and also outside the building. In the future, we like to be able to turn to the wall and do just this. Think of the wall as an interactive wall or as one being "covered" by a high resolution electronic wallpaper providing the functionality needed and being networked to other places.

Scenario Two: Dynamic team rooms. In typical team work, a team meets and often divides up the work by assigning subtasks, then breaks up so that individuals and subgroups can go off to do their work. After some time, perhaps the next day, the full team meets again and discusses the results which form the basis for the next phase of cooperation. In a time-critical situation, it would be very useful if one can reduce this cycle time of full team meeting/ subgroup meetings. An alternative is to provide ways for subgroups to split up *during the meeting* in the same room, do their work, rejoin and then immediately merge the results. Providing adequate information technology support for this scenario requires a team or project room which is equipped with components and resources which are very flexible so that they can be reconfigured dynamically and on-demand in order to meet the requirements of changing team work situations. Our analysis of this scenario includes a plenary situation and different subgroup or individual work constellations. The plenary is characterized by the full team sitting in chairs and facing a large public display. An example of subgroup work is that people move their chairs and group them in one corner of the room, discuss their task and exchange ideas. Another subgroup walks over to an ad-hoc meeting table, stands around it, views and edits tables and diagrams. A third constellation is that people walk up to a whiteboard at the wall, draw sketches and annotate them with scribbles. Of course, it might be the case that some of these "subgroups" consist only of one person using the devices for individual work. It is our vision that the chairs, the table, and the wall are interactive devices providing support for these cooperation and interaction situations via embedded information technology.

Our approach to meet the requirements of these scenarios is based on the roomware concept. By *roomware* we mean computer-augmented things resulting from the integration of room elements (e.g., walls, doors, furniture like tables, chairs, etc.) with computer-based information devices. The resulting roomware components are interactive. They provide support for the creation, editing, and presentation of information. They are networked and therefore have access to worldwide information. The chairs and the table are also mobile due to wireless networks and stand-alone power supply.

The general goal of developing roomware is to make progress towards the integration of architectural spaces and information spaces. In the context of CSCW, we have a specific goal, i.e. to develop reusable components which can be tailored and composed to form flexible and dynamic "cooperation landscapes" serving multiple purposes: team or project rooms, presentation suites, information foyers, etc. Both goals have in common that we also have to develop new forms of human-computer interaction for multi-user, multiple-displays environments. In section 4, we describe the initial set of roomware components we develop in the i-LAND project. It consists of an interactive electronic wall (*DynaWall),* an interactive table *(InteracTable),* and mobile and networked chairs with integrated slate computers *(CommChairs).*

3.2 A^3-Environments

In our discussion of the local vs. global dimension, we raised the issue of identifying and locating devices in buildings and in global distributed environments. Using sensors, one can acquire information on who (people, roomware components) is located where, connected with whom and interacting with whom. This can be used to structure the cooperation process among people and to provide the corresponding means and information needed by an individual or a team. The next scenario illustrates part of this idea.

Scenario Three: The room that knows you and your team. A project team enters the room. The "room senses" the members of the team, compares this list to previous users of the room, identifies the team and the project discussed at the last meeting. If the team wants to, the room configures itself restoring the state of the last meeting including the set of documents they were working on before. The content and the structure of the information is displayed again on the different roomware components (e.g., the interactive wall, the interactive table). Thus, the team can continue right where they were at the end of the last meeting.

A generalization of this idea results in what we call *attentive, active, and adaptive rooms or environments* (*A^3-environments).* "Attentive" means that the environment is able to observe a room, a hallway or another area of the building it is assigned to. It will be able to identify and locate people by various means (e.g., active badges, image recognition, video analysis). The same is possible for tagged and/or networked devices, e.g., the roomware components. Being informed about who and what is where and what is going on, the A^3-environment can be "active" by (re)acting in correspondence with predefined rules, e.g., providing information that there is a prepared agenda for the current meeting, that a team member who attended the last meeting is not present, etc. Furthermore, it can be "adaptive" by configuring the whole room or part of it according to context information on what the room should be used for, e.g., displaying the work environment of a specific project team. A^3-environments are adaptive in the sense of auto configuration but they can also be adapted by the user or the team. In both cases, the same room (or hallway, foyer, etc.) can be orchestrated for multiple purposes providing interactive information landscapes for changing usage conditions.

4 i-LAND: An interactive Landscape for Creativity and Innovation

In order to test the feasibility of the concept of a cooperative building, the i-LAND project was initiated. Its overall goal is to develop a work and collaboration environment which responds to the demands of new work practices and organizational innovation as they are characteristic for ad hoc and on demand teams, multiple-purpose use of project-team rooms, etc. Besides the overall goal, i-LAND serves as a testbed for the development of roomware and A^3-environments and their tailorability to specific requirements of potential user groups. It will also provide the basis for evaluating the ideas and concepts by applying them to a specific application scenario, i.e. the support of so-called creative teams. Examples are teams designing a new product, developing a marketing strategy for an existing product, developing a perspective on the future strategy of a company, etc.

4.1 Motivation and Requirements

The importance of supporting different work phases, e.g., involving subgroups as in the second scenario, has been shown in several empirical studies we conducted to evaluate our meeting support systems (Streitz *et al.*, 1994). On the one hand, we found that certain features of the software – in our case the provision of hypermedia functionality – facilitates the division of labor in team work and resulted in better results in group problem solving (Mark *et al.*, 1995, 1996). On the other hand, we investigated the role of different personal and public information devices (networked computers, interactive whiteboard) and different combinations of them for meeting room collaboration in a recent empirical study (Streitz *et al.*, 1997). The results show that the groups which developed a balanced proportion of individual work, subgroup activities, and full team work achieved better results than those groups which stayed most of the time in the full-team work configuration. The degree of flexibility to work in different modes was largely determined by the combination of information devices provided to the team. Offering a wider range of devices or roomware components resulted in more flexibility.

While these encouraging results were obtained in existing electronic meeting rooms, these constellations do not provide the necessary flexibility of assigning different physical workspaces within a meeting room to subgroups and individuals. Existing electronic meeting rooms usually employ one large static table and computers on top of it or mounted in the table as we also did in the past (Streitz *et al.*, 1994). Thus, it is not possible to allocate and (re)configure the resources in terms of information objects/spaces, roomware components in a flexible way. This flexibility is a design goal of high priority for the i-LAND environment.

This design goal also requires to develop new means of distinguishing between individual and (sub)group work modes and using the detection of behavior and actions in the real world instead of setting parameters via complicated interfaces for initiating and terminating computer-supported cooperation (e.g., sharing of information) between people. The spatial flexibility and mobility of the roomware components requires the use of wireless networks for connecting the information devices embedded in the room and in the furniture and an independent power supply.

The current application scenario for i-LAND is to serve as a collaborative work environment facilitating especially creativity and innovation processes in teams. In order to inform our design and to tailor the generic components to this purpose, we are investigating specific requirements in terms of appropriate roomware components and creativity techniques supporting these processes. To this end, we are conducting an empirical study involving interviews of creative teams in selected companies in Germany. These teams are concerned with product design, marketing campaigns, strategic future planning, etc. We are describing and analyzing their current work practices using existing rooms, furniture, equipment, and creativity techniques. On this basis, we identify shortcomings of conventional practices and equipment. Furthermore, we are interviewing these teams about their requirements for support of creative collaborative work in the near future but inquire also about their fantasies and visions for the far future.

4.2 Roomware components of i-LAND

We defined an initial set of roomware components which will be described in detail in the following subsections:

- *DynaWall* - an interactive electronic wall
- *CommChairs* – mobile and networked chairs with integrated interactive devices
- *InteracTable* – an interactive table.

In addition, to bridge the real world and the virtual world we are designing a mechanism for establishing relations between real objects and information objects. We call this mechanism *Passage*.

While each category of the roomware components has a value of its own, the full benefit will only be available in their integration and combined use corresponding to the different work phases identified before. This is achieved via the integration of the roomware components in an application, in this case the i-LAND scenario. The technical integration is achieved by employing wireless networks connecting all components as well as by a client-server software based on the cooperative hypermedia framework COAST (Schuckmann *et al.,* 1996). Fig. 3 shows our plan for the i-LAND environment.

The roomware components of i-LAND have been or are being built. The software providing the required functionality is still under development. Therefore, one has to keep in mind, that not all features described are already implemented in full but are part of the concept and the requirements for the components.

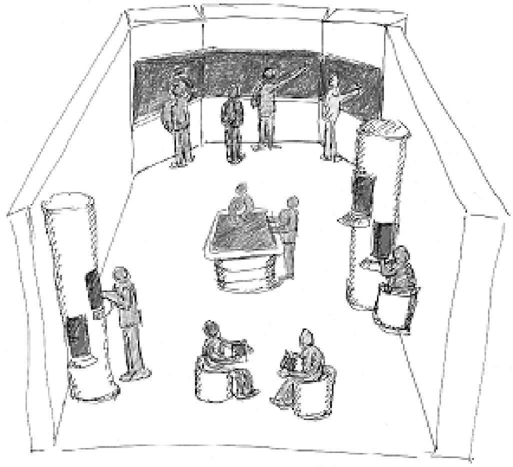


Fig. 3. View of the planned i-LAND environment showing three subgroups and two individuals.

4.2.1 DynaWall

Project teams in so-called project rooms often use large areas of assembled sheets of paper (usually covering the walls) to create and organize their information. Examples are large project overviews in terms of its parts, their relationships and dependencies. However, the need for large visual areas is not restricted to the organizational aspect. In many cases, even more important is the possibility for displaying, annotating and editing large contents which is not without problems, especially in the paper-based situation. Display space on paper or via an electronic information device is a crucial point for most visually-oriented tasks.

Furthermore, in the electronic version the requirement is to be able to interact with the content in a very intuitive way relying on standard gestures known from the interaction with the physical objects in the real / paper world.

The objective of the DynaWall is to represent a computer-based device that serves these needs. It can be considered an “interactive electronic wall” represented by a touch-sensitive information device. The current realization in the AMBIENTE Lab at GMD-IPSI uses three rear-projection interactive whiteboards (SMART Boards™) with a total display size of 4.5 m width and 1.1 m height and a resolution of 3072 by 768 pixels. It fills one side of the room completely (see Fig. 4). The DynaWall enables groups like project teams to display and to interact with large information structures collaboratively. The goal is to support two or more persons, either individually, in parallel or sharing the whole display space.

The size of the DynaWall creates a new set of problems for human-computer interaction. It should be possible that information objects can be taken at one position and put somewhere else on the display or thrown from one side to the opposite side. Dialog boxes always should appear in front of the current user(s). User interface components should always be at hand, etc.

Fig. 4. Two CommChairs in front of the DynaWall.

4.2.2 CommChairs

The CommChairs (see Fig. 5) represent a new type of furniture. They combine the mobility and the comfort of armchairs with high-end information technology.

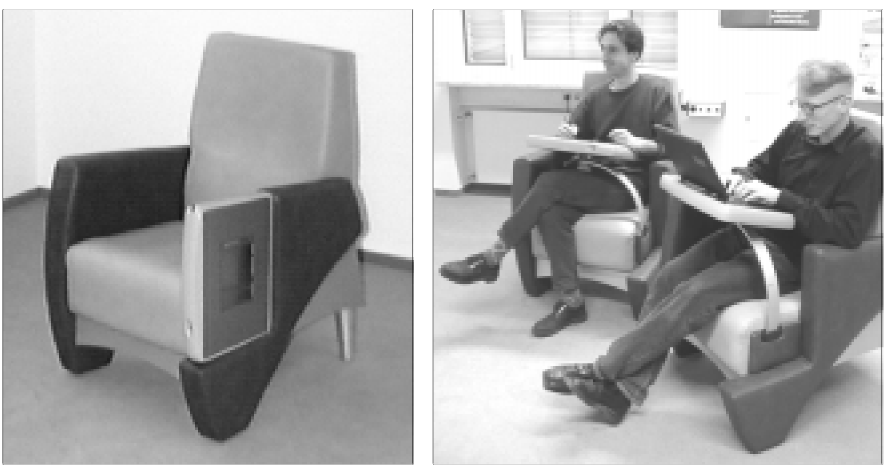


Fig. 5. CommChairs and their usage.

So far, we developed two variants: one with an integrated information device and one with a docking facility for plugging in laptops or other mobile computers carried along (Fig. 6).

Fig. 6. left - CommChair with integrated pen-based computer,
right - CommChair with docking facility for standard laptops.

Each chair is provided with an interface for wireless networks and an independent power supply for maximum flexibility and mobility. We use a radio-frequency network for connecting to the Ethernet. Because of this connection, one can access world-wide information while sitting in the chair.

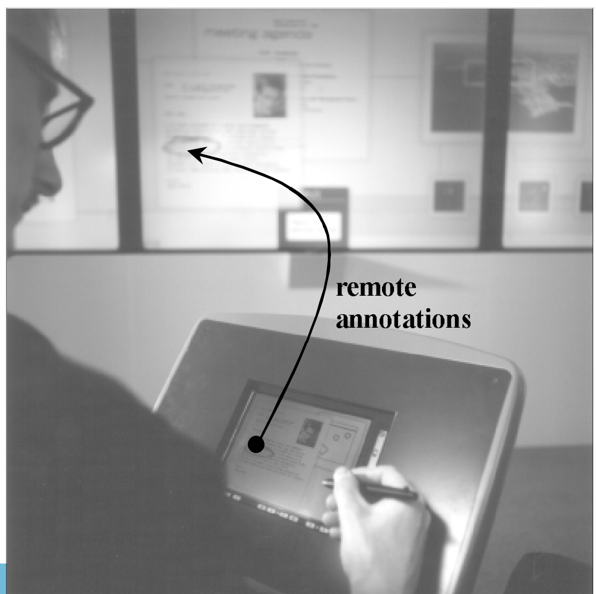


Fig. 7. Accessing the DynaWall from the CommChair.

Furthermore, the chairs enable people to make private annotations and notes and to connect to shared workspaces, displayed on devices like the InteracTable or the DynaWall. Users can edit and annotate objects displayed on these roomware components not only locally but also remotely (Fig. 7).

Localization of the chairs in a room and the identification of the person sitting in the chair will be done automatically based on sensors we will provide in the room. This allows to bring up and configure the personalized environment. Furthermore, this enables also to establish network connections and then shared information displays simply by moving chairs together.

Built-in audio and video communication facilities, leaving messages for other people sitting in that chair as well as tactile notification of incoming calls/information are further aspects that are planned in this part of the i-LAND project.

4.2.3 InteracTable

The InteracTable is the first in a series of information devices that investigates general shapes and orientations of interaction areas. It is designed for display, discussion, and annotation of information objects by a group of two to six people sitting or standing around the table.

The current stand-up version of the InteracTable (Fig. 8) is built as a vertical rear-projection unit with a touch-sensitive display surface. Inside the table, an LCD beamer projects a high-resolution image of 1024x768 pixels to the top of the table. The integrated wireless network provides the InteracTable with a high degree of flexibility.

Fig. 8. Informal discussion at the InteracTable.

Since a round or oval-type display has no selected orientation as, e.g., top and bottom and left and right at the desktop computer, one has to provide new means of interaction. Information objects displayed on the table have to be rotated and shuffled across the surface in correspondence to different view perspectives of the users standing or sitting around the table. Manipulation is done by gestures using fingers or pens, annotations by voice and/or pen. In addition, an infrared keyboard is available for more extensive text-entry tasks.

4.2.4 Passage

Transportation of complex information structures collected from various sources very often is an awkward task: numerous tools have to be started, the material has to be arranged, maybe copied, and finally sent to the new location, e.g., by e-mail attachments, ftp or similar services. When the person that sends this information arrives at the new location, a similar activity of unpacking the material begins. The idea of Passage describes an elegant mechanism of connecting information structures in the digital, virtual world of computers with a real-world object. Such a detectable object, we call it a *Passenger*, can be seen as a physical bookmark into the virtual world. One can connect information to it, take it, carry it physically to the new location, e.g., in the pocket of a shirt, and simply by putting it on a special device called *Bridge*, the information is displayed immediately. It is no longer necessary to open windows, browse hierarchies of folders, worry about mounted drives and doing similar annoying actions. Passage is a concept for ephemeral binding of content to an object.

A Passenger does not have to be a special object. Any uniquely detectable object may become a Passenger. Since the information structures are not stored on the Passenger itself but just linked to it, people can either turn personal objects into a Passenger, like a watch, ring, or glasses, or they can use objects that are neutral in terms of personal value. In the current i-LAND scenario, we use small wooden building blocks of different size, shape and color that are inexpensive and can be bought in every toy store. The only restriction Passengers have is that they can be identified by the hardware and the software of the Bridge and that they are unique.

The connection between an information structure and an object is established by making use of a Bridge device (see the tray in the middle of the DynaWall shown in Fig. 4). A user simply puts an object on the Bridge, selects the material to be transported on the screen and activates a widget that links this material to the object, turning it into a Passenger. At the same time, the Passenger is registered in a central repository of valid Passengers. When such a Passenger is carried to and put on another Bridge, its software, which has access to the repository via the computer network, recognizes the Passenger, collects the material, mounts network drives if necessary and finally displays the information on the screen that is connected to the Bridge. By using another widget, a Passenger retires, i.e. the connection between the object and the information is removed. As a first approach and just for demonstration purposes, we implement the Bridge as a scale with fine granularity that is connected to a computer via the serial port. Our sample Passengers, the small wooden building blocks, all have a different weight, and are uniquely identifiable.

5 Related Work

The roomware concept, the development of different roomware components as instantiations of this concept and their integration in the i-LAND environment is related to and was inspired by different developments in human-computer interaction and computer-supported cooperative work. The most relevant examples are augmented reality, ubiquitous computing, and collaborative workspaces, in particular meeting support systems. One perspective is that we develop new ideas for human-computer interaction and apply them to the design of collaborative work environments. A complementary perspective is that we extend interaction techniques by cooperative functionality in order to develop ubiquitous and collaborative workspaces.

5.1 Augmented Reality

Augmented reality can be viewed as the counter-approach to artificial or virtual reality. It is concerned with the use of computational devices in order to augment our perception and interaction in the physical world. The devices that add computational information to the appearance and/or use of reality can take various forms. For an overview of initial work see Wellner *et al*. (1993). Examples are the DigitalDesk that uses a video projection of a computer display as an overlay on paper documents on a real desk (Wellner, 1993), the Chameleon prototype consisting of a small portable, display and spatially-aware palmtop computer that can act as a window into the information space (Fitzmaurice, 1993), and the NaviCam (Rekimoto & Nagao, 1995) providing context-sensitive information about objects in the physical environment via a palmtop displaying combined video images and data.

In comparison to the DigitalDesk, the InteracTable provides a touch-sensitive interactive display and is not using an overlay of video projections. With respect to NaviCam or Chameleon, we currently do not plan to develop special devices that add computational information to the visual appearance of reality. Instead, in the roomware concept, everyday objects as, e.g., furniture are augmented with computational functionality in order to add value with respect to cooperation support.

A related approach to augmented reality is the notion of tangible bits and ambient media (Ishii & Ullmer, 1997). It is based on the idea of graspable user interfaces (Fitzmaurice *et al.*, 1995) where a physical "brick" can be used to manipulate a virtual object. Tangible bits was also inspired by the "marble answering machine" developed by Bishop (see Poynor, 1995) where incoming phone calls are indicated by (physical) marbles which can be placed on a specific area for playing the message. While these interfaces are concerned with foreground activities of users, ambient displays – realized as elements in the periphery of the architectural space – provide interfaces to background information (Ishii & Ullmer, 1997).

Our "Passage" mechanism is also inspired by the "marble answering machine" but it extends this idea by using physical objects not only as representatives for digital information but also as means for physical transport of information between different roomware components, e.g., the DynaWall and the InteracTable.

5.2 Ubiquitous Computing, Multiple Devices

Pursuing the approach of augmented reality seriously implies to have many, loosely spread and networked information devices around, with displays of different sizes, instead of a (central) desktop computer. This is the concept of ubiquitous computing (Weiser, 1991, 1993) and – in a related way - of ubiquitous media (Buxton, 1997). Some of the devices will stand out and be recognized as computers, others will be "invisible" as they are embedded in the environment. Our roomware approach concentrates especially on integrated devices that are embedded in furniture, like chairs and tables, as well as in architectural elements of buildings, such as doors or walls.

Once the physical space is filled with multiple devices, the issue arises on how to transfer information between them in an intuitive and direct way and, more general, how to interact with them. This problem is addressed, e.g., by the "pick-and-drop" technique (Rekimoto, 1997, 1998 in this volume). We address these challenges by a similar technique called "take-and-put"; furthermore by throwing and shuffling of information objects, especially on large displays, and by our "Passage" concept for the physical transportation of information.

5.3 Collaborative Workspaces

With respect to existing work in computer-supported cooperative work, especially meeting support systems as, e.g., CoLab (Stefik *et al.*, 1987), GroupSystems (Nunamaker *et al.*, 1995), ShrEdit in the CREW Lab (Olson *et al.*, 1993), Tivoli (Pederson *et al.*, 1993), and our own previously developed DOLPHIN system in the OCEAN Lab (Streitz *et al.*, 1994, 1997), our new approach is different because of the notion of dynamic offices and mobile roomware components. This allows flexible and dynamic creation and allocation of workspaces in different parts of a room in correspondence with the current mode of the group activity instead of having a fixed setup of chairs around a static table. It enables new methods of establishing cooperation and sharing of information, e.g., by simply moving chairs in close spatial proximity in order to form a subgroup. Thus, initiating cooperation between two or more people can be based on an intuitive and natural physical movement instead of selecting parameters in a number of menus and dialogue boxes.

Other relationships concern the type of work supported and the type of software used for this support. With respect to supporting creative work, the most common technique is brainstorming. It has been demonstrated that computer-supported brainstorming results in more number of ideas than verbal brainstorming. One reason among others is that the possibility of parallel input decreases production blocking (Gallupe *et al.*, 1991). GroupSystems (Nunamaker *et al.*, 1995) and ShrEdit (Olson *et al.*, 1993) are examples of systems supporting brainstorming.

There are limitations with existing systems we like to overcome. We will provide a suite of creativity techniques which can be combined in a flexible and seamless way. Furthermore, existing systems are usually limited to text items. Another issue is the flexibility of the available structures in order to overcome the limitations of more or less flat or hierarchical list structures. This will be partially based on our previous work by using hypermedia structures for the underlying representation (Streitz *et al.,

1994) but we will complement it by new concepts. Therefore, as part of our approach in i-LAND, we plan to develop new visualization metaphors for presenting content and structures of our “interactive landscape for creativity and innovation”.

6 Conclusions and Future Work

We have presented a comprehensive approach for the integrated design of real architectural spaces and virtual information spaces. The central idea is the concept of roomware components facilitating interactive and cooperative functionality at every place in a cooperative building. This paper described the current state of the design considerations, the first realization of roomware components and the requirements for the software currently under development.

Since the described components of i-LAND introduce new, to some degree unfamiliar forms of human-computer interaction, there is a need to evaluate their usefulness and their usability in a systematic fashion. Since i-LAND offers various configurations and combinations of the components, we have to evaluate also how to match different cooperation scenarios with different roomware configurations and to investigate their influence on the work processes. This evaluation effort is an important aspect of our iterative design cycle.

For updates of the work on i-LAND and related activities in the AMBIENTE Division at GMD-IPSI, please visit our website: http:// www.darmstadt.gmd.de/ambiente/

Acknowledgement

We like to thank Peter Seitz, Christian Müller-Tomfelde, Shin'ichi Konomi, Petra Rexroth, Michele Gauler, Wolfgang Reischl, Daniel Warth, and Jochen Denzinger for their valuable contributions to different parts of the i-LAND project. Furthermore, we extend special thanks to Dan Russell and Ralf Steinmetz for their comments improving earlier versions of this paper.

References

1. Bly, S., Harrison, S, Irwin, S. (1993). Media Spaces: Bringing people together in a video, audio and computing environment. *Communications of the ACM*, 36 (1), 28-47.
2. Buxton, W. (1997). Living in augmented reality: Ubiquitous media and reactive environments. In: K. Finn *et al.* (Eds.), *Video-Mediated Communication*. Erlbaum, 363-384.
3. Fitzmaurice, G. (1993). Situated information spaces and spatially aware palmtop computers. *Communications of the ACM*, Vol.36 No.7 , 38-49.
4. Fitzmaurice, G., Ishii, H., Buxton, W. (1995). Bricks: Laying the foundations for graspable user interfaces. *Proceedings of CHI‘95 Conference*, ACM. pp. 442-449.
5. Gallupe, R.B., Bastianutti, L.M. & Copper, W.H. (1991). Unblocking brainstorming, *Journal of Applied Psychology*, 76, pp. 137-142.

6. Ishii, H., and Ullmer, B. (1997). Tangible Bits: Towards seamless interfaces between people, bits and atoms. *Proceedings of CHI'97 Conference*, ACM. pp. 234-241.
7. Mark, G., Haake, J.M., and Streitz, N. A. (1995). The Use of Hypermedia in Group Problem Solving: An Evaluation of the DOLPHIN Electronic Meeting Room Environment. *Proceedings of E-CSCW '95*, Kluwer Academic Publisher. pp. 197-213.
8. Mark, G., Haake, J.M., and Streitz, N.A. (1996). Hypermedia Structures and the Division of Labor in Meeting Room Collaboration. *Proceedings of CSCW '96,* ACM. pp. 170-179.
9. Nunamaker, J.F. Briggs, R.O. & Mittleman, D.D. (1995). Electronic Meeting Systems: Ten Years of Lessons Learned. In: Coleman, D. and Khanna, R. (Eds.), *Groupware: Technology and Applications*. Prentice-Hall Inc., pp. 149-193.
10. Olson, J., Olson, G., Storrosten, M., and Carter, M. (1993). Groupwork close up: A comparison of the group design process with and without a simple group editor. In: T. Malone, N. Streitz (Eds.), *Special Issue on CSCW of ACM TOIS.* 11 (4), 321-348.
11. Pedersen, E., McCall, K., Moran, T., Halasz, F. (1993). Tivoli: An electronic whiteboard for informal workgroup meetings, *Proceedings of InterCHI'93 Conference*, pp. 391-398.
12. Poynor, R. (1995). The hand that rocks the cradle. *I.D. - The International Design Magazine*. May-June 1995.
13. Rekimoto, J. (1997). Pick-and-Drop: A direct manipulation technique for multiple computer environments. *Proceedings of UIST'97*. ACM Press. pp. 31-39.
14. Rekimoto, J. (1998). Multiple-Computer User Interfaces: A cooperative environment consisting of multiple digital devices. In: N. Streitz et al. (Eds.), *Cooperative Buildings - Integrating Information, Organization, and Architecture. Proceedings of CoBuild'98.* LNCS 1370 (this volume). Springer: Heidelberg, pp. 33-40.
15. Rekimoto, J. , Nagao, K. (1995). The world through the computer: Computer augmented interaction with real world environments. *Proceedings of UIST'95*. ACM Press. pp. 29-36.
16. Schuckmann, C., Kirchner, L., Schümmer, J., and Haake, J.M. (1996). Designing object-oriented synchronous groupware with COAST. *Proceedings of CSCW '96 Conference*. ACM Press. pp. 30-38.
17. Stefik, M., Foster, G., Bobrow, D., Khan, K., Lanning, S., Suchman, L. (1987). Beyond the chalkboard: Computer support for collaboration and problem solving in meetings. *Communications of the ACM*, 30 (1), 32-47.
18. Streitz, N. (1995). From individual work and desktop-based collaboration to ubiquitous meeting environments. In: P. Brusilovsky, P. Kommers, N. Streitz (Eds.*), Multimedia, Hypermedia, and Virtual Reality*. LNCS 1077. Springer; Heidelberg. pp. 149-163.
19. Streitz, N., Geißler, J., Haake, J., and Hol, J. (1994). DOLPHIN: Integrated meeting support across LiveBoards, local and desktop environments. *Proceedings of CSCW '94 Conference,* ACM Press. pp. 345-358.
20. Streitz, N., Rexroth, P., Holmer, T. (1997). Does "roomware" matter? Investigating the role of personal and public information devices and their combination in meeting room collaboration. *Proceedings of E-CSCW'97*, Kluwer Academic Publishers. pp. 297-312.
21. Weiser, M. (1991). The Computer for the 21st Century. *Scientific American*, 1991, 265 (3), 94-104.
22. Weiser, M. (1993). Some computer science issues in ubiquitous computing. *Communications of the ACM*, 36 (7), 75-84.
23. Wellner, P. (1993). Interacting with paper on the DigitalDesk. *CACM*, 36 (7), 86-96.
24. Wellner, P., Mackey, W., Gold, R. (Eds.) (1993). Computer-Augmented Environments: Back to the Real World. Special Issue of *Communications of the ACM*, 36 (7).

Ambient Displays: Turning Architectural Space into an Interface between People and Digital Information

Craig Wisneski, Hiroshi Ishii, Andrew Dahley
Matt Gorbet, Scott Brave, Brygg Ullmer, Paul Yarin

Tangible Media Group
MIT Media Laboratory
20 Ames Street, Cambridge, MA 02139 U.S.A.
Email: wiz@media.mit.edu

Abstract. We envision that the architectural space we inhabit will be a new form of interface between humans and online digital information. This paper discusses Ambient Displays: a new approach to interfacing people with online digital information. Ambient Displays present information within a space through subtle changes in light, sound, and movement, which can be processed in the background of awareness. We describe the design and implementation of two example Ambient Displays, the ambientROOM and Ambient Fixtures. Additionally, we discuss applications of Ambient Displays and propose theories of design of such interfaces based on our initial experiences.

Keywords. ambience, awareness, attention, periphery, ambient displays, graspable media, physical interface

1 Introduction

Ambient \Am"bi*ent\, a. Surrounding, encircling, encompassing, and environing.
-Oxford English Dictionary

Nature is filled with subtle, beautiful and expressive ambient displays that engage each of our senses. The sounds of rain and the feeling of warm wind on our cheeks help us understand and enjoy the weather even as we engage in other activities. Similarly, we are aware of the activity of neighbors through passing sounds and shadows at the periphery of our attention. Cues like an open door or lights in an office help us subconsciously understand the activities of other people and communicate our own activity and availability.

Current personal computing interfaces, however, largely ignore these rich ambient spaces, and resign to focusing vast amounts of digital information on small rectangular windows. Information is presented as “painted bits” on flat screens that must be in the center (foreground) of a user’s focus to be processed (Fig. 1). The interactions between people and digital information are now almost entirely confined to the conventional GUI (Graphical User Interface) comprised of a keyboard, monitor, and mouse.

Ambient Displays takes a broader view of display than the conventional GUI, making use of the entire physical environment as an interface to digital information. Instead of various information sources competing against each other for a relatively small amount of real estate on the screen, information is moved off the screen into the physical environment, manifesting itself as subtle changes in form, movement, sound, color, smell, temperature, or light. Ambient displays are well suited as a means to keep users aware of people or general states of large systems, like network traffic and weather. We believe that this approach will be a critical step in moving beyond current interface limitations.

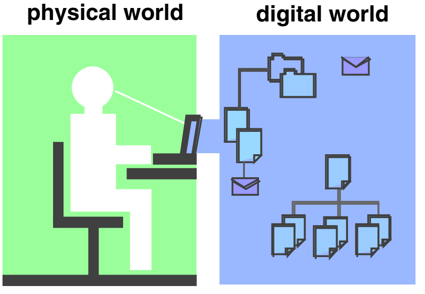


Fig. 1. Personal Computing: Looking through a small window

Ambient displays are envisioned as being all around us. They are suited for the home environment and everyday life. People have a need to feel connected to others, especially loved ones, and ambient displays can aid in this connection. Other well suited spaces include highly specialized environments where many streams of information need to be constantly monitored. Examples might include an aviation cockpit, an atomic power plant control room, or a car. Further, we envision ambient media stretching out towards everyday life, being incorporated into people's workplaces, and into future visions of wearable computers people might have on their bodies.

Two projects that explore the Ambient Displays concept are the ambientROOM and Ambient Fixtures. We will discuss their motivation, implementation, and application, and further attempt to tease out lessons we have learned through their creation.

2 Related Work

2.1 Tangible bits

Ambient Displays is part of our broader "Tangible Bits" vision that blurs the boundary between the physical and digital worlds to create an interface between humans and digital information in cyberspace. We are turning each state of physical matter - not only solid matter, but also liquids and gases - within everyday architectural spaces into interfaces (Ishii & Ullmer 1997).

The key ideas of "Tangible Bits" are concepts of graspable media and ambient media (Fig. 2). We are developing ways to:

- allow users to grasp and manipulate bits (digital information) with their hands at the center of attention, and
- enable users to be aware of background bits at the periphery of perception using ambient media.

2.2 Awareness in human computer interaction

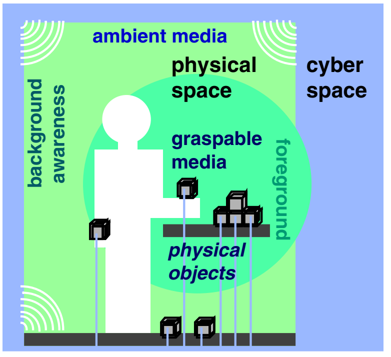


Fig. 2. Tangible Bits: Inhabiting a Digitally Augmented Architectural Space

Awareness is the state of knowing about the environment in which you exist; about your surroundings, and the presence and activities of others. Awareness is essential in collaboration to coordinate the activities in a shared workspace. Awareness support discussed in the Computer Supported Cooperative Work (CSCW) community has focused on the representation of the state of collaborators in a geographically distributed context. Technological devices such as remote cursors, multiple scroll bars, audio cues, and low framerate video have been proposed to support the awareness of remote collaborators' activities. Dourish and Bly's Portholes project (1992) is an example of an awareness support system using low resolution, low framerate video.

Our notions of ambient media were, in part, inspired by the Fields and Thresholds work of Dunne and Raby (1994) and the Live Wire of Jeremijenko (Weiser, Brown 1995). These projects explored a theme of peripheral awareness of external activity, especially of activity attributable to people. The AROMA project (Pederson & Sokoler, 1997) further investigates ideas of peripheral awareness. These researchers share many of our ideas, especially with respect to the use of subtle and abstract displays.

In this paper, we present a new kind of awareness support methodology, including, but not limited to, the "awareness" of people's activities. Rather, we extend them to include dynamic information systems, such as weather, stock values, and network traffic.

2.3 Cognitive science theories related to ambient displays

In designing the interface that humans use to access computation, the fundamental human issues of attention, perception, and mental representation come into play. In fact, these factors are central to how humans use an interface tool, yet, in the field of cognitive science, attention, perception, and representation building remain relatively illusive and mysterious.

In designing ambient displays, we have looked at two bodies of research about humans. First is the “ecological” perspective, as put forth by such psychologists as J.J. Gibson (1979) and Ulric Neisser (1972). Gibson and Neisser have written extensively about humans within the natural world. Their work, consequently, has focused on perception as an active task that humans engage in within their environment. Gibson introduced the theory of “affordances”, which is central to our ideas on physicality and control.

The second body of literature that has driven our designs draws from attention studies in experimental psychology. Especially relevant is the notion of the “cocktail party effect”- the ability of a person to selectively move his or her attention around a busy environment (Cherry, 1953). One goal in designing ambient environments is to exploit this human capability. We also examined the divided attention studies of Treisman, Rensink, and others. Treisman’s work shows that information can be processed, even if it is not in the foreground of a person's attention (1960). Rensink and others have tried to more systematically explore how attention can effect the perception of a scene (1997). While significant strides have been made in understanding the basic ways attention works, very few experimental results can be easily applied to complex, chaotic environments.

3 The ambientROOM

The ambientROOM is based on the Personal Harbor™ product from Steelcase Corp., a 6’x8’ enclosed mini-office installation (Fig. 3). The ambientROOM surrounds the user within an augmented environment – “putting the user inside the computer” – by providing subtle, cognitively background augmentations to activities conducted within the room.

We developed the ambientROOM as a platform supporting the expression of online digital information with “ambient media” – ambient light, sound, airflow, and physical motion used as peripheral displays at the background of user attention.

Fig. 3. ambientROOM based on Personal Harbor™ (Steelcase)

3.1 Human activity awareness

People have a need to feel connected to others, especially, people they care about. Yet, some people argue that personal computing isolates people. Ambient media can be used to create a persistent, yet non-intrusive connection between loved ones, bringing people a sense of community through shared awareness.

Many of our prototypes are centered on this kind of information. Connecting people is an attractive, powerful application of networked technology that has shown its usefulness in forms like email, paging, and telephones. Our work extends these ideas by connecting people through their physical environment.

Water Ripples

One display in the ambientROOM allows the user to have some awareness of the activity of a distant loved one. For our first instance, we expressed the activity of a resident hamster in our laboratory, for which cage temperature, light level, and wheel motion had already been instrumented and displayed on a web page.

Initially, a small, motorized representation of the hamster was configured to vibrate as the hamster's wheel rotated. This type of display proved somewhat intrusive, so alternate display mappings were explored. Now, the hamster representation could be grasped by the user and pointed at the ceiling of the room. This action "transfers" the vibration to the motion of a solenoid in a shallow water tank. A lamp reflecting off of the water then produces rippling shadows on the ceiling.

Active Wallpaper

Another display also provides awareness of the physical presence of others. Electric field sensors are used to measure the level of human activity in a work area. They are setup to sense the number of people in an area, and how often people generally come and go. This activity is represented by a pattern of illuminated patches projected onto an inner wall of the ambientROOM. When activity is low, the movement of these spots is minimal, but as activity levels increase, so does the motion of the spots, providing a visual display of remote activity.

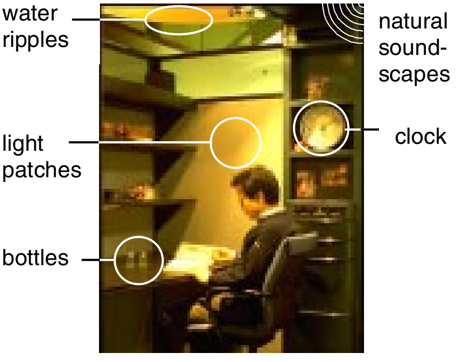


Fig. 4. Ambient media displays and controls

Ambient Sound

Auditory displays have been implemented as well. A soundscape arises out of activity on the digital whiteboard in our group's workspace. When the board is in use, the sounds of the dry-erase pens rubbing against the board are transmitted into the ROOM in a low-volume, subtle way. This gives the inhabitant of the ROOM some awareness of activity in the central workspace.

All of these examples have concerned awareness of a local event. However, we are particularly interested in relating global events to our local space.

3.2 Global system awareness

The “awareness of people” application can be extended to monitor large systems of people, or behaviors that arise out of other large systems. Ambient displays could be suited to display general trends of stock values for a trader, network traffic information for a system administrator, and so on.

Another particularly interesting application to display is information about natural phenomena, such as atmospheric, astronomical, or geographical events. Displays such as these can give people an indication of the state of the world around them.

The ambientROOM contains a subtle but audible soundtrack of birds and rainfall, whose sound volume and density are modulated in conjunction with variations in room lighting. Thus, approximate quantities can be monitored with this display, for instance, the number of unread email messages or the level of a stock portfolio. Also, in this instance, the lighting in the ROOM changes according to the time of day.

It should be noted that GUI interfaces and ambient interfaces do not comprise a dichotomy of purpose and function. Subtle, background ambient displays are meant to co-exist with, and complement, foreground tasks. Also, background displays can move into the foreground, and vice versa. Users control this through their personal state of awareness, and sometimes, through physical controls.

3.3 Controls

To provide a means of controlling the ambient activity displays, several activity controls were deployed in the ambientROOM. Small physical bottles are employed as graspable “containers” for digital content, such that opening a bottle “releases” information into the ROOM. One bottle contains information about the load on our computer network, and when opened, that data is represented in the ROOM as the sound of vehicular traffic.

A second activity control, a large wall-mounted clock with exposed hands, allows navigation through temporal events. A user recently absent from the room might wish to review activity displays from the past few hours, or skim forward in time to peruse anticipated events. In response to manipulation of the clock’s time, the ambientROOM prototype shifts through the ambient sound and lighting displays of past hours.

We try to build controls to be self-explanatory. The gesture of opening and closing a bottle is a simple way of accessing information. The physical rotation of clock hands is equally simple and powerful. We envision that physical controls will be widespread in future environments, and will incorporate easy-to-use, gestural interfaces like the ones found in the ambientROOM.

3.4 Implementation

The implementation of the ambientROOM is designed to support quick prototyping. The ROOM is enabled with a host of products such as samplers, synthesizers, lighting-control boards, and software that allows easy synchronization of many media elements. Sensing and display in the ambientROOM are coordinated with Opcode's MAX software running on a Macintosh. MIDI-controlled dimmers adjust room lighting, a sampler manages sound playback, and rotation and electrical contact sensors monitor manipulation of the clock and bottle. An electric field sensing unit is used to monitor human movement in surrounding spaces. Video projectors augment the ROOM's clock, walls, and desk surface.

4 Ambient Fixtures

Ambient Fixtures are standalone ambient media displays. We have taken concepts developed within the ambientROOM, and have moved them out into an open space, inhabited by many people. In the ambientROOM, the user is "inside the computer," while Ambient Fixtures allow us to externalize the displays and distribute them throughout an architectural space.

We have implemented two Ambient Fixtures: the Water Lamp and Pinwheels. The Water Lamp is an extension of the ceiling water ripples of the ambientROOM and the Pinwheels explore ideas of physical movement as a display medium.

4.1 The Water Lamp

The first ambient fixture we developed is the Water Lamp (Fig 5). A light shines upward through a pan of water, which is actuated by changing information. This action produces changing patterns of light projected onto the ceiling of a room.

Fig. 5. Design sketch of the Water Lamp

The Water Lamp is composed of a wooden base, 3 aluminum support tubes and an acrylic water tray. There are 3 small Shindengen 6V solenoids mounted above the water tray. These solenoids are controlled by a single circuit board. When actuated the solenoids tap on the surface of the water in the tray, causing ripples. The refracted light is shown as wave-like patterns on the ceiling.

The Ambient Fixtures are based upon a common control platform- the iRX 2.0 PIC Microcontroller Board designed at the MIT Media Lab by Robert Poor. The iRX board accepts commands over a serial input line from a computer to control each fixture. This allows us to distribute fixtures throughout our research space. TCL based software sends commands to the Fixtures. Information can be relayed from the internet or other networked information source and be routed to the appropriate fixture.

4.2 Pinwheels

The pinwheels evolved from the idea of using airflow in the ambientROOM (Fig. 6). We found that the flow of air itself was difficult to control, and hence, became a problematic tool with which to convey information. As an alternative, we found that the visual representation of airflow could be quite useful. The pinwheels spin at different speeds based upon their input information source.

The pinwheels are made from folded fiberglass mounted on the shaft of a small Mabuchi 5.9V DC motor. Four pinwheels were connected to each iRX control board. Pulse width modulation controls the speed at which the motors spin.

Ambient Fixtures are especially suited to the display of information like natural phenomena, such as atmospheric, astronomical, or geographical events. For instance, an atmospheric scientist might map patterns of solar wind into patterns of Pinwheel flow in a room. Other users might want to be aware of tension in the Earth’s fault-lines, giving an indication of earthquake activity. They could represent this through an array of Water Lamps. In ways like these, ambient media can provide a means for people to feel connected to the world around them.

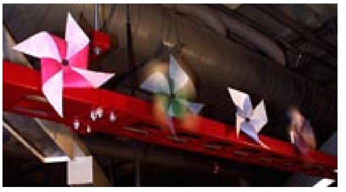


Fig. 6. Array of Pinwheels

5 Discussion

Our explorations have given us insight into many research issues that arose in designing ambient displays. In this section, we will discuss some of these issues.

5.1 Mapping of information sources

In the presentation of ambient media, one of the key elements is the modality chosen to present a source of information. Information can be presented through any of the five senses, and the choice of which sense or senses to use at any given time is one of the first key choices in designing an interface.

The choice of modality for the background media should be considered with the person’s foreground task in mind. For example, if a person is in their office performing a visually intensive foreground task- say, writing software- a visually based ambient display on the wall behind the person might not be as effective as an auditory display. Similarly, when a person is performing an intensive auditory task, like talking on the phone, ambient information might be better presented through non-auditory ways, or for example, in visual ways like shadows on a wall. However, if the modality and spatial configuration of a particular ambient display is substantially altered during the course of use, people may become confused about the display mapping being employed.

The mapping of data from information source to ambient display is a key consideration and challenge for ambient media. Whether it is sensors picking up activity of a person, or streams of data coming from dynamic natural systems, at the base level, almost all sources of information are represented by a computer as a stream of numbers. A designer of ambient media must transform the data into a display that successfully maps the information into a new form. The designer must decide how the source gets mapped and the location of where it gets mapped (i.e. where in visual, tactile, or audio space).

We expect that some styles of mappings will be more effective than others. For instance, many people reported that the sampled, looped sounds of water in the ambientROOM became annoying after months of repetition. In particular, sounds that are looped in some kind of discernable way tend to become annoying very quickly. In contrast, MIT Media Lab researchers Tom White and David Small (1997) created a project called "Stream of Consciousness" which employed a real stream of water flowing down a bed of rocks. The physicality in this project creates a kind of acoustic noise that most people seem to prefer.

Choices have also been made between abstract and literal displays. For the "active wallpaper" in the ambientROOM, fuzzy spots represent the movement of people. We also experimented with placing a far-infared camera in the space being monitored, and projecting its out-of-focus image on the wall of the ROOM. Many people thought the camera-based display felt intrusive, as the mapping was too literal and privacy had not been respected. Because of issues like this, we have focused thus far on more abstract display mappings. Still, we recognize that displays must not be so abstract that users cannot infer their meaning.

5.2 Thresholds / transition from background to foreground

Ambient displays go largely unnoticed until some unexpected thing in the display makes it come into the foreground of attention. Depending on a user's state of attention, there exists a threshold where this background to foreground transition is made. In a few cases during our design explorations, it became apparent that the ambientROOM was too "busy". At times when all the displays were running at once, the ROOM was so full of brisk activity, that people had difficulty maintaining concentration on a foreground task. Many media elements going at once caused each display to exhibit a lower threshold for the background to foreground transition, creating an "information overload" effect.

In an effort to better control the output of our displays, experiments are being done that test the thresholds of each design instance, and how they change when used in conjunction with each other. These experiments examine changing modalities of background information based on a person's foreground task.

5.3 Learning effect

Ambient media likely has a learning effect: like driving a car, after a while, a person's perception changes based on his or her familiarity with the environment. Just like a car driver knows how to switch from the gas to the brake while turning the radio station, we expect a person in an ambient environment will learn how and where to look for information. The length of time a person spends in the environment will likely influence the person's facility for using it. We wish to further study how quickly a person can "get up to speed" in different kinds of ambient environments.

6 Conclusion

When ambient media is fully assimilated into future environments, appliances of all kinds may likely change. Air-conditioners may be computationally enabled to change the flow of air to convey information. Lamps bases may not only hold a light bulb in place, but will contain processors and motors so that the light can become a display medium.

The function of many common appliances may be extended to connecting people with information they otherwise would not be able to perceive, or at least not be able to get in such an easy fashion. We do not intend to distance people from their immediate environment even further. Ambient media should allow for further and increased coincidence of human interaction, rather than less. We seek to determine what kinds of interaction ambient media really promotes, and how we can design displays to promote human interaction, rather than detract from it.

We have discussed the motivation, implementation, and applications behind our ambient displays. We have also attempted to identify lessons we have learned through our work. Many more studies need to be done before a solid theory will arise, and hopefully, our work will help guide others along with us in this pursuit.

Acknowledgements

We would like to thank Betty Lou McClanahan, Caraway Seed and all of our group's undergraduate researchers. We would also like to thank Steelcase for their support.

References

Cherry, E.C. (1953). Some experiments on the recognition of speech with one and two ears. Journal of the Acoustical Society of America, 25, 975-979.

Dourish, P., & Bly, S. (1992). Portholes: Supporting Awareness in a Distributed Work Group. In: Proceedings of CHI 92. ACM Press, 541-547.

Dunne, A., Raby F. (1992). Fields and Thresholds. Presentation at Doors of Perception 2. http://www.mediamatic.nl/Doors/Doors2/DunRab/DunRab-Doors2-E.html

Gibson, J.J. (1979). The Ecological Approach to Visual Perception. Lawrence Erlbaum Associates..

Ishii H., & Ullmer, B. (1997). Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In: Proceedings of CHI '97, ACM Press, 234-241.

Neisser, U. (1976). Cognition and Reality. W H Freeman & Co.

Pedersen, E., Sokoler, T. (1997). AROMA: Abstract Representation Of Presence Supporting Mutual Awareness.In: Proceedings of CHI '97, ACM Press, 51-58.
Rensink R.A., O'Regan J.K., & Clark J.J. (1997). To See or Not to See: The Need for Attention to Perceive Changes in Scenes. Psychological Science, 8, 368-373.
Treisman, A. (1960). Verbal cues, language, and meaning in selective attention. Quarterly Journal of Experimental Psychology, 12, 242-248.
Weiser, M., & Brown, J.S. (1995). Designing Calm Technology. http://www.fxpal.xerox.com/chi97/white-papers/Mark%20Weiser.html
White, T., & Small, D. (1997). Stream of Consciousness. http://acg.media.mit.edu/projects/stream/

Multiple-Computer User Interfaces: A Cooperative Environment Consisting of Multiple Digital Devices

Jun Rekimoto

Sony Computer Science Laboratory Inc.
Takanawa Muse Building
3-14-13 Higashigotanda, Shinagawa-ku, Tokyo 141 Japan
Tel: +81 3 5448 4380
Email: rekimoto@csl.sony.co.jp
URL: http://www.csl.sony.co.jp/person/rekimoto.html

Abstract. Traditional graphical user interfaces (GUIs) are mainly designed for an environment consisting of a single display and a set of single input devices. However, in the near future we will be using a number of computers (and other electronic devices). Just as we often combine several physical devices to perform a task in a real world, it should also be possible to use multiple computers more effectively. This paper proposes the notion of multiple-computer user interfaces in a future cooperative environment. We also describe an interaction technique that allows a user to transfer digital information to other electronic devices placed in a physical environment, and a digital whiteboard system that effectively uses a multiple-device architecture.

Keywords. multiple-device user interfaces, ubiquitous computing, pick-and-drop, digital whiteboard systems, cooperative buildings

1 Introduction: From a single-device UI to a multi-device UI

As Mark Weiser (1991) and many other visionaries foresaw, our physical space will be filled with a number of digital devices. Some of them will be invisible (i.e., embedded in the environment); others will remain visible like today's desktop computers. In a meeting room today, for example, participants often use a notebook PCs while presenters use a digital whiteboard. Even now, in individual work environments, we often use more than one computer at a time (such as a desktop PC and a PDA).

In our daily lives, it is natural to combine several physical "tools" to achieve a task. However, it is not so easy to combine multiple computers and devices. One reason is that computers (and other electric devices) are not designed to be used in multiple-computer (multiple-device) environments. For example, even simple GUI techniques such as cut-and-paste or drag-and-drop do not work across computer boundaries.

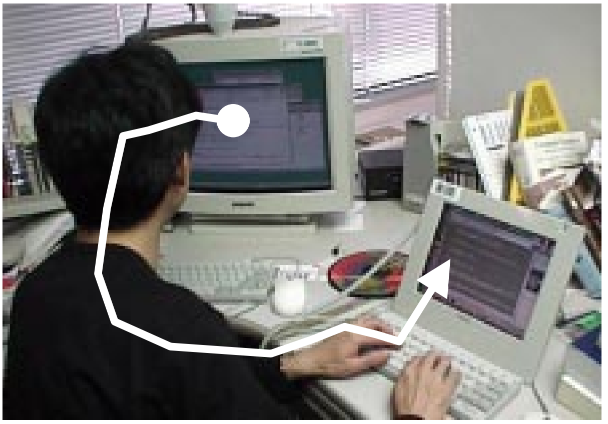


Fig. 1. Data transfer through the human body? A typical difficulty when dealing with two or more computers in a same place.

Fig. 1 shows a typical difficulty one encounters when using more than one computer. The user here reads a text segment such an URL on the left display, and then types it into the computer at the right, even though these two computers are connected to the network. Since there is no easier way (such as drag-and-drop) to transfer data between the two, he prefers to transfer the data by hand. One survey revealed that more than 60% of the software engineers in Sony's development division experience similar problems.

We believe that future computer interfaces must be designed to be used in a multiple-computer (or multiple-device) environment. More specifically, interaction techniques must overcome the boundaries among multiple devices, and that environments must accommodate to the dynamic addition of new devices.

Another important issue is a physical aspect of computer devices. For example, we can not simply apply the same UI design for small (palmtop sized) and large (wall-sized) computers, just as memo-pads and whiteboards are used quite differently in our everyday world. Physical position and direction of computer devices are also important. A display in a public meeting space would be used as a shared digital bulletin board for a group, while a small screen device attached on the wall of a personal work space would show schedule of an individual. When a table-top becomes a computer display, it would be meaningless to add a "menu-bar" on top of the (table) screen, because there is no notion of "upper-side" of the computer display.

In this paper, we describe our recent attempts in designing interaction techniques and systems based-on the notion of multiple-computer user interfaces. In the next section we will discuss a data-transfer technique (called Pick-and-Drop) between multiple computers, followed by a description of a digital whiteboard design using the multiple-device approach.

2 Pick-and-Drop: An interaction technique for transferring digital information in a physical environment

The *Pick-and-Drop* is our initial attempt to design a multiple-computer user interface (Rekimoto 1997), focusing on data transfer problems in multi-comp environments. Like the commonly used drag-and-drop, pick-and-drop is a pen-based direct manipulation technique for transferring digital data such as icons on a computer screen. Unlike drag-and-drop, pick-and-drop allows a user to physically pick up a digital object from one screen, carry it through real space, and drop it in a different place, or even on a different computer screen. Just like chopsticks are used for moving a piece of food from one dish to another, pick-and-drop provides a method whereby a user can physically carry data as if it were a real object.

Although these operations can also be implemented by using remote copy or shared file systems, we feel that pick-and-drop offers more natural and direct way to manipulate a digital object in a real space. Using traditional data transfer methods, users have to deal with many symbolic concepts such as machine names, file names, and directory path names, even if target computers are physically placed side-by-side. On the other hand, data transfer with pick-and-drop is more direct and visible as opposed to symbolic. Users can be aware of physical position on computer screens, just like moving a physical object in a real world.

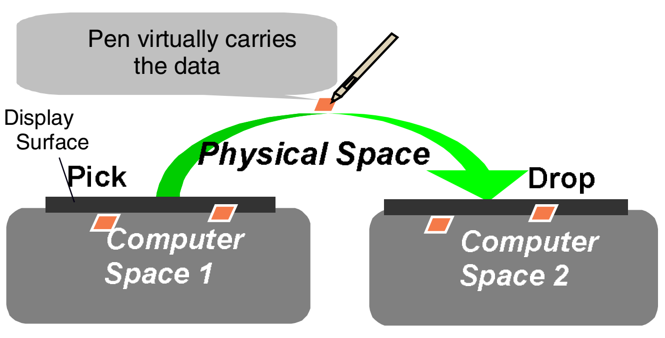


Fig. 2. Pick-and-Drop supports data transfer among multiple devices through the physical space

We developed the multi-computer Pick-and-Drop without adding actual storage capabilities to the pen device, by introducing the concept of *Pen IDs*. In our design, each pen is assigned a unique ID. We are currently using a combination of modifier buttons (attached to the pen as a side switch) to represent IDs. Based-on the WACOM electromagnetic stylus technology, this pen ID as well as the pen position is readable from the computer (screen) when a pen is closer enough to its screen. We also assume that all computers are connected to the network (either wired or wireless). There is a server called the "pen manager" on the network.

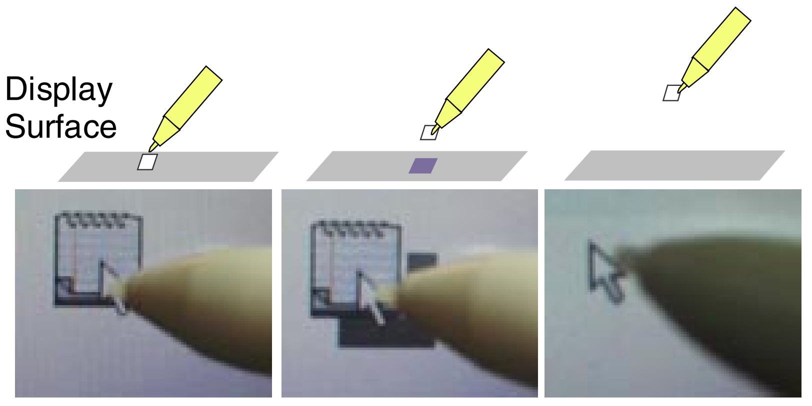


Fig. 3. A data icon with shadow indicates pen holding data without dropping it on the screen. (left: the pen touches the screen, and dragging an icon, middle: the pen is holding data near the screen, and an icon with shadow appears on the screen to show the pen's data type, right: the pen moves away from the screen, and the icon disappears)

When a user taps an object (typically an icon) on the screen with the pen, the pen manager binds its object ID to the pen ID. This binding represents a situation in which the pen virtually holds the object (even though the pen itself does not contain any storage). When the user moves the same pen towards the other display, the pen manager supplies the type of the bound object to the display. Then the data icon with shadow appears on the display below the current pen position to show the data the pen is holding, before actually dropping it on the screen (Fig. 3). At this moment, the pen does not touch the screen. Finally, when the user touches the display with the pen, the pen manager asks the first computer to transfer the data to second computer.

Since each pen has its own ID, simultaneous Pick-and-Drop operations by more than one pen can overlap. This feature would be useful in a collaborative setting.

3 Applications of Pick-and-Drop

Once data transfer between multiple devices becomes widely available, we will have greater flexibility in designing a physical work environment by combining multiple digital devices (Fig. 4 shows typical usage of pick-and-drop between different types of computers). For example, a computer augmented drafting desk could consist of a large main display and several small palm-sized computers. These small computers would act as temporary work places for drawing data (i.e., tangible paste buffers), tool palettes, or data-carrying devices to store and transfer drawing materials. The user could physically deploy these small devices around the main display to configure

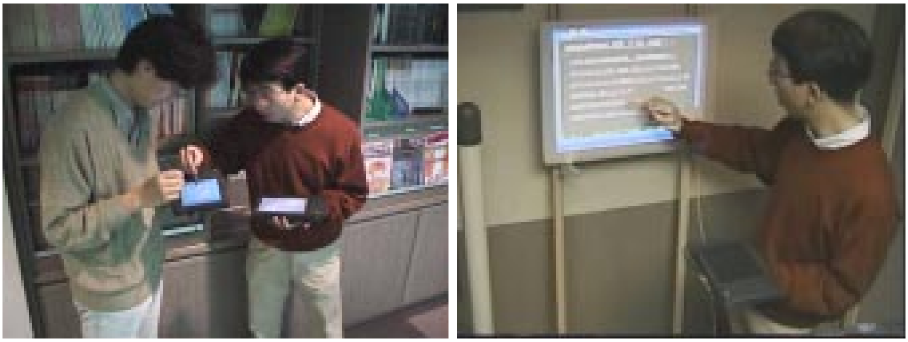


Fig. 4. Applications of Pick-and-Drop (left: transferring data between two PDAs, right: picking up information from the kiosk terminal)

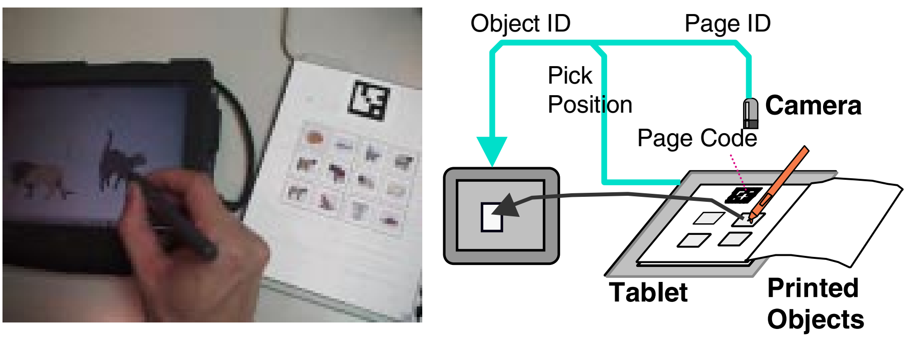


Fig. 5. PaperIcon: Data transfer between printed material and a computer screen.

his/her own work environment. Data transfer among all the devices would be supported by the pick-and-drop.

We also have implemented data transfer from paper materials to digital surfaces using a combination of a tablet and a camera (Fig. 5). The printed page is placed on a pen sensitive tablet and a camera is mounted over the tablet. The camera is used to identify the opened page by reading an ID mark printed on it. The user can freely flip through the booklet to find a desirable icon. The system determines which icon is picked based on the page ID and the picked position on the tablet. With this technology, even physical material such as clip-art books can be a part of a multiple-computer environment.

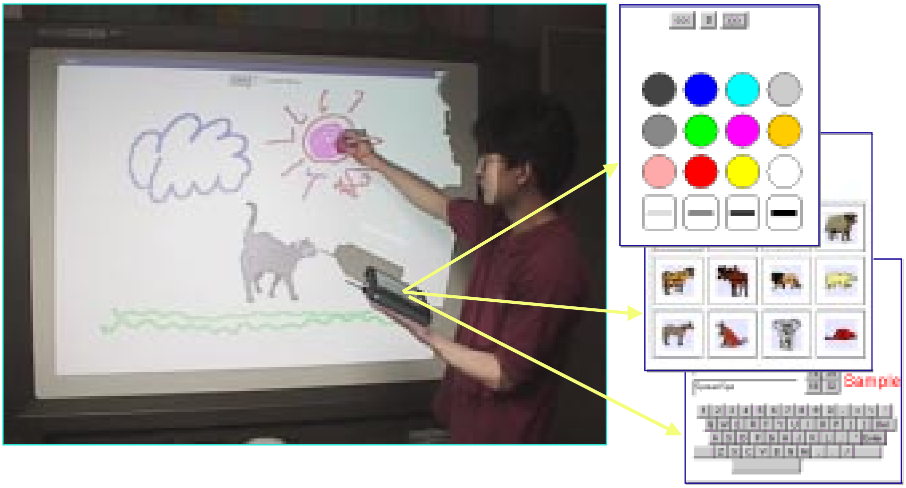


Fig. 6. A digital whiteboard system using the multiple-device architecture. Just as an oil-painter effectively uses a palette in his/her hand, the hand-held device offers an easy way to create a new text/graphics object, to select existing data from network, to select pen attributes, and to control the whiteboard application. Note that the same pen can be used to manipulate both of the whiteboard and the hand-held computers.

4 Applying a Multi-computer Configuration to a Digital Whiteboard Design

Another possible multi-device configuration is to use a hand-held tablet as a support for large (whiteboard-sized) display interfaces (Rekimoto 1998).

Traditional digital whiteboard systems such as Xerox LiveBoard (Elrod *et al.,* 1992) often suffer from a limited capability to enter text and the handling of existing data. The large display surface of the whiteboard also makes traditional GUI design ineffective. For example, placement of menu bars or tool bars becomes a problem because they might be out-of-reach from users. Single thread features of current GUI design also prohibits parallel activities among collaborators.

Existing digital-whiteboard systems have tried to address these problems by enhancing the design of user interfaces only on a whiteboard. However, we feel that if some of the whiteboard functions were given to the participants via hand-held devices, it would offer a simple, yet powerful solution to these problems.

Based-on this multiple-device design, we have developed a digital whiteboard system using a palm-sized computer as a control palette (Fig. 6). The user can select a color and brush type for the pen by tapping the control panel on the palm-sized

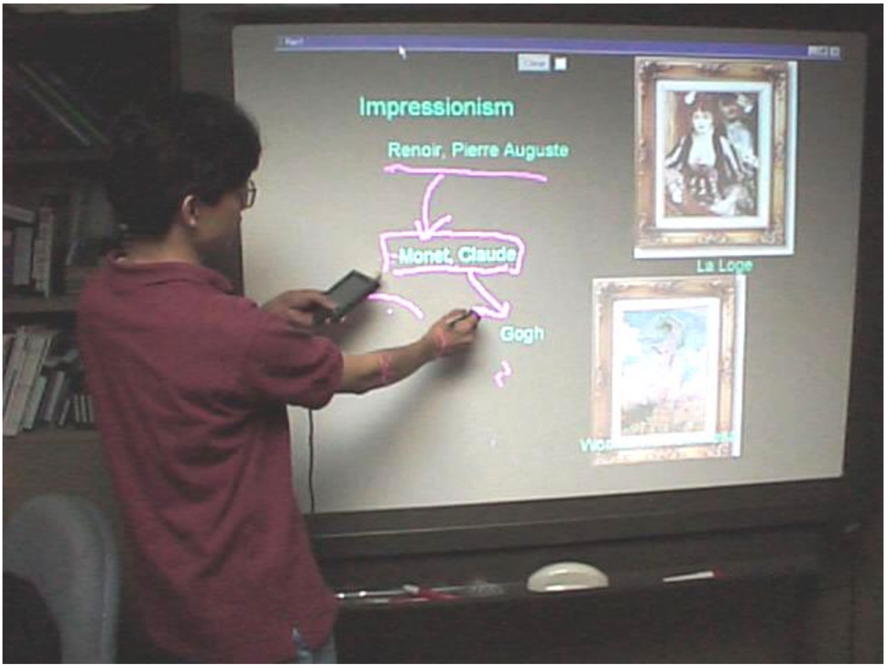


Fig. 7. A lecture-style session using a PDA in the left hand and a digital pen in the right hand. A lecturer can select text or graphics items using a PDA, then paste it on the whiteboard with the left hand. Note that the PDA contains a position sensor and the user can specify the paste position by placing the PDA on the whiteboard.

tablet. This metaphor is similar to physical oil painting using a canvas and a palette. This interaction style is advantageous for drawing on a large display, because users do not have to click on a tool-palette on the whiteboard, which might be out of reach. The user can also transfer digital data between any participating computers (e.g., whiteboard, palmtop, and other user's palmtop), using pick-and-drop operations.

Fig. 7 is another variation of a digital whiteboard that also employs a multiple-device configuration. This setting is designed for a lecturer in a classroom. The system allows a lecturer to select and attach data elements from the screen of the Pilot PDA in the left hand to the whiteboard. A lecturer can freely decide which data should be displayed next, according to the flow of his/her talk. The lecturer can also add hand-drawn diagrams or texts using a pen in his/her right hand. The result becomes a mixture of a whiteboard-based lecture style with digital presentation information. Such an effect can not be realized by using only traditional presentation software.

Fig. 8. A prototype data picking wand

5 Summary and Future Projects

In this paper, we have argued the importance of multiple-computer user interfaces in future cooperative environments. We also have described an interaction technique based on a metaphor of digital-physical fusion, called the Pick-and-Drop, with several example applications. We are currently working on extending the concept of information picking to the more general domain.

Fig. 8 Shows the prototype data picking "wand" --- a new style of future PDAs. Using the combination of camera and infrared sensors, it supports data transfer between several digital devices (e.g., VCR and computer) as well as non-digital materials (e.g., a physical bulletin board and a document cabinet) in our daily environment.

References

1. Weiser, M. (1991). The Computer for the Twenty-first Century. Scientific American, vol. 265, (3), 94-104.
2. Rekimoto, J. (1997). Pick-and-Drop: A Direct Manipulation Technique for Multiple-computer Environments, In: Proceedings of UIST'97, 31-39.
3. Rekimoto, J. (1998). A Multiple Computer Approach for Supporting Whiteboard-based Interactions, In: Proceedings of CHI'98 (in press).
4. Elrod, S., Bruce, R., Gold, R., Goldberg, D., Halasz, F., Janssen, W., Lee, D., McCall, K., Pedersen, R., Pier, K., Tang, J., & Welch, B. (1992). LiveBoard: A large interactive display supporting group meetings, presentations and remote collaboration, In: Proceedings of CHI'92, 599-607.

A Prototype Intelligent Environment

Michael H. Coen

MIT Artificial Intelligence Laboratory
545 Technology Square
Cambridge, MA 02139
Email: mhcoen@ai.mit.edu

Abstract. This paper presents our laboratory's Intelligent Room, an experimental environment for bringing computation into the realm of ordinary, everyday activity and enabling natural human-computer interaction. We first present the notion of an Intelligent Environment and describe how it differs from other paradigms in human-computer interaction. We then discuss our Intelligent Room's hardware and software components and one of the room's current applications. We also outline criteria for designing and evaluating highly interactive spaces.

Keywords. intelligent environments, cooperative buildings, artificial intelligence, embedded computation

1 Introduction

This paper presents an existing prototype environment, known as the Intelligent Room, which attempts to bring computation into the realm of ordinary, everyday activity in a seamless way. The Intelligent Room is a research platform for exploring the design of intelligent spaces and was created to experiment with different forms of natural human-computer interaction during what is traditionally considered non-computational activity. It is equipped with numerous computer vision, speech and gesture recognition systems. These allow the room to watch where people are moving and under certain circumstances where and how they are pointing, and to listen to a fairly wide variety of spoken language utterances. The room is also capable of controlling a wide range of software applications, e.g., web browsers and interactive maps, and physical hardware including several VCRs and steerable video cameras.

We have created several environments that run within the Intelligent Room, ranging from an intelligent living room to a futuristic command post for planning disaster relief. The goal of implementing these interactions is to explore and help define what

This material is based upon work supported by the Advanced Research Projects Agency of the Department of Defense under contract number F30602—94—C—0204, monitored through Rome Laboratory and Griffiss Air Force Base. Additional support was provided by the Mitsubishi Electronic Research Laboratories.

an intelligent environment should be and to determine what roles such environments could potentially play in our lives.

In this paper, we first define the notion of an *intelligent environment* and how it differs from other embedded and multimodal systems and more generally from other paradigms in human-computer interaction. We then describe our laboratory's Intelligent Room hardware and software components as well as a current room application. We next detail unique issues encountered while building these interactive, multimodal systems as well as issues that should be considered during their design.

2 Motivation

Intelligent environments (IEs) are spaces in which computation is seamlessly used to enhance ordinary activity. One of the driving forces behind the emerging interest in highly interactive environments (Bobick *et al.,* 1996; Coen, 1997a; Coen, 1997b; Coen *et al.,* 1998; Cooperstock *et al.,* 1997; Torrance, 1995) is to make computers not only genuinely user-friendly but also essentially invisible to the user. Interaction with them should be in terms of forms that people are naturally comfortable with. The user-interface primitives of these systems are not menus, mice and windows but gesture, speech, affect, and context. Their applications are not spreadsheets and word processing but intelligent rooms and personal assistants. At least in theory, it should be possible for a person to forget she is using a computer while interacting with one.

Intelligent environments are both embedded and multimodal and thereby allow people to interact with them in natural ways. By being embedded, we mean these systems use cameras for eyes, microphones for ears, and ever-increasingly a wide-range of sophisticated sensing technologies to connect with real-world phenomena. Computer vision and speech recognition/understanding technologies can then allow these systems to become fluent in natural forms of human communication. People speak and gesture and move around when they intercommunicate. For example, by embedding user-interfaces this way, the fact that people tend to point at what they are speaking about is no longer meaningless from a computational viewpoint and we can build systems that make use of this information. In some sense, rather than make computer-interfaces for people, we want to make people-interfaces for computers.

Coupled with their natural interfaces is the expectation that these systems are not only highly interactive (i.e. they talk back when spoken to) but also that they are useful for ordinary activity. They should enable tasks historically outside the normal range of human-computer interaction by connecting computers to naturally occurring phenomena that have traditionally been outside the purview of contemporary user-interfaces. Rather than restrict computers to the backwaters of data processing, we envision them as active partners in everyday life that are conversant with the phenomena with which we are innately familiar and in which we experience our lives. Thus, once we build systems that can understand events patently obvious to any five-year-old child (such as someone walking into a room), we can create applications that extend into the *real world* in a way never before possible and perhaps never even previously conceived of.

2.1 Why this isn't Ubiquitous Computing

Intelligent environments require a highly embedded computational infrastructure; they need many connections with the real world in order to participate in it. However, this does not imply that computation need be everywhere in the environment nor that people must directly interact with any kind of computational device. Our approach is to advocate minimal hardware modifications and "decorations" (e.g., cameras and microphones) in ordinary spaces to enable the types of interactions in which we are interested. Rather than use the computer-everywhere model of ubiquitous computing – where for example, chairs have pressure sensors that can register people sitting in them or people wear infrared-emitting badges so they can be located in a building – we want to enable unencumbered interaction with non-augmented, non-computational objects (like chairs) and to do so without requiring that people attach high-tech gadgetry to their bodies (as opposed to the approach in (Want *et al.*)).

There are several motivations behind our approach. The first is that unlike Weiser (1991), we make unabashed use of research from the Artificial Intelligence (AI) community. Many AI research areas have achieved sufficient maturity to offer useful, standalone subsystems that can be incorporated into larger, general-purpose projects. For example, up until quite recently, real-time computer vision systems were inordinately expensive and computationally dependent on physically large workstations. (The earliest person tracking system in the Intelligent Room required a Silicon Graphics Reality Engine and two additional Indy workstations.) However, it is now possible to set up sophisticated, real-time computer vision systems on inexpensive, readily available platforms. The proliferation of these systems has led to a flourishing in computer vision research and to useful, stand-alone systems.

Although a pressure sensor on a chair may be able to register that someone has sat down, it is unlikely to provide other information about that person, e.g., her identity. Visual data from a single camera can provide (in theory and increasingly often in practice) far more information than simple sensing technologies. This includes the person's identity, position (DeBonet *et al.,* 1996), gaze direction (Stiefelhagen *et al.,* 1997), facial expression (Blank *et al.,* 1995; Lien *et al.,* 1997), gesture (Wilson *et al.,* 1998), and activity (Davis *et al.,* 1997). While there has yet to be a coherent system that unifies all of these capabilities, several prototypes are currently under development. Furthermore, enhancing the capabilities of a computer vision system often requires modifying only the software algorithms that process incoming images, not adding new hardware. Once the physical infrastructure for an intelligent environment is installed, its visual capabilities can be updated and enhanced without necessarily adding to or modifying the room's sensory components. Also, because the room senses at a distance, objects, in particular furniture, do not need to be physically augmented and wired for the room to become aware of them.

Not requiring that people attach gadgets to their bodies in order to interact with the environment is a primary goal of this research. While wearable sensing and computing devices (Starner *et al.,* 1997) may be appropriate in laboratories or under other special conditions, it seems highly inconvenient to require them in general. Assuming intelligent environments will ever make it out of research laboratories and into commercial, government, and residential domains, it seems reasonable to suppose that they must feel as natural and to some degree invisible as possible. Towards this end, we argue that intelligent environments should not place artificial burdens on their inhabitants, particularly when unobtrusive sensing technology can achieve the same results.

Rather than viewing our approach as completely at odds with that of ubiquitous computing, the two can be seen as natural complements. Ubiquitous computing is very much about making computation so commonplace that it is no longer obtrusive, and intelligent environments are concerned with bringing computation into new realms in which it has historically had no role. Together, both approaches can go a long way towards making computation a natural part of everyday existence.

2.2 Other Related Work

The DigitalDesk project (Wellner, 1991; Newman *et al.,* 1992) was an early and influential system that had a bird's eye view of a desktop through an overhead video camera. It recognized and responded to predetermined hand gestures made by users while interacting with real paper documents on the surface of a desk. For example, people could select text on paper with their finger in the same way someone would with a mouse on a monitor. The primary contribution of this work was the idea of using the physical world as its own representation in a user-interface. The Intelligent Room has a desktop environment directly motivated by the DigitalDesk, which recognizes a wider range of complex hand gestures (Dang, 1996). Much other work has built upon the DigitalDesk framework, e.g. Saund (1996). Interactions with objects more complex than paper are described in theory by Fitzmaurice *et al.* (1995) and in practice by, for example, Rauterberg *et al.* (1997).

Other substantial efforts towards highly interactive environments include an automated teleconferencing office (Cooperstock *et al.,* 1997) and an immersive fictional theater (Bobick *et al.,* 1996). Each of these projects makes use of embedded computation to enable unusual human-computer interactions, e.g., vision-based person tracking. However their modal processing is extraordinarily specific to their applications, and the applicability of such carefully tuned systems to other domains is unclear. The Classroom 2000 project (Abowd *et al.,* 1996) is an educational environment that automatically creates records linking simultaneous streams of information, e.g. what the teacher is saying while a student is writing down her notes on a digital pad. The potential for automated annotation in an intelligent environment is a promising area that deserves more exploration.

Mozer (1998) describes a house that automatically controls basic residential comfort systems, such as heating and ventilation, by observing patterns in its occupants behavior. Having complex interactive environments learn via observation is likely to be essential to making them generally useful. Given that VCR programming is still a subject of general mirth, the prospect of programming homes is likely to cause widespread consternation. Paradiso *et al.* (1997) present the sensory component of an immersive musical environment that combines a touch-sensitive carpet with a Doppler radar system. Together, these locate people moving on the carpet and measure their upper-body kinematics in order to create musical sounds. How this system would be applied to other application domains remains to be determined.

Related user-interface work such as (Cohen *et al.,* 1996) uses multimodal interface technology to facilitate human interaction with a preexisting distributed simulator. In doing so, it provides a novel user-interface to a complex software system, but it is one that requires tying down the user to a particular computer and a specific application. We are interested in creating new environments that support never before conceived of applications – applications that historically have never involved computation.

3 The Intelligent Room

Our approach with the Intelligent Room has been to transform an ordinary conference room into an HCI research platform that connects with real-world phenomena through a host of computer vision, speech and gesture recognition systems. These allow the room to watch where people are moving and under certain circumstances where and how they are pointing, and to listen to a fairly wide variety of spoken language commands and questions.

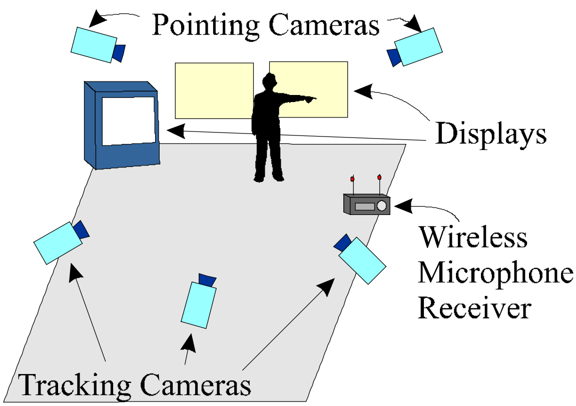


Fig. 1. A simplified layout of the Intelligent Room

Fig. 1 shows a simplified layout of the Intelligent Room without its furniture, which consists of a large conference table surrounded by a number of chairs. The room contains several large video displays that can be driven by any of the room's multiple cameras, VCRs, a television tuner, or any of several workstations. The workstations are used in particular to display computer-controlled Web browsers or custom graphical applications, such as interactive maps. A matrix switcher allows arbitrary connections between the room's audio/visual inputs and outputs.

Hardware devices in the room are computer-controlled via any of three mechanisms. The room's lighting is controlled through a serially interfaced X-10 system. Many of the room's devices, including several VCRs, two matrix switchers, and three steerable cameras, contain RS232 serial ports and directly interface with software agents specifically written to control them. The room can also generate infrared remote control signals to access consumer electronics items (namely, objects that don't have serial ports), including a television and stereo system.

3.1 Speech Input

Before a person enters the room, she dons a wireless, lapel microphone that connects to the room's speech recognition systems. Although requiring the wearing of a microphone violates the spirit of an unencumbered interaction, there were no practical alternatives for capturing users's speech when the room was initially designed. We hope in the future to make use of recent work in remote sound localization and capture (Renomeron *et al.,* 1997) to eliminate the need for every occupant to wear their own microphone.

In general, the room ignores spoken utterances from the lapel microphones not specifically directed to it. To get the room's attention, a user must stop speaking for a second and then say, *"Computer,"* out loud. The room responds with an audible chirp (so familiar to Star Trek viewers) to indicate that it is ready for input. She is then free to issue a command or ask a question, such as *"What's the weather forecast for Boston?"* The room subsequently provides an audible click to indicate that the statement was understood. This hands-free style of interaction along with audio feedback allows a user to ignore the room's presence until she explicitly needs to communicate with it.

For processing spoken utterances, we use both the Summit (Zue, 1994) and DragonDictate speech recognition systems in parallel. Each of these supports recognition of continuous speech and some degree of word spotting. Summit is particularly adept at providing syntactic variability and supports a topically narrow but syntactically unconstrained set of recognized utterances entered via a bigram model. DragonDictate supports explicit construction of context-free recognition grammars and allows external applications control over low-level aspects of its behavior. This makes it ideal for using as a component in larger systems. The room interfaces with the START natural-language information retrieval system (Katz 1990) to enhance its ability to understand complex linguistic input primarily provided as output of the Summit system.

3.2 Computer Vision

Among the room's primary stereo vision systems is a three camera, multi-person tracker (Davis *et al.,* 1997) that can follow up to four people moving in the room in real-time. A debugging window from the tracker is shown in Fig. 2. Because the system is based on background differencing (shown in the bottom right window), people seem to disappear if they stand still for too long but are relocated once they resume motion. This is not a problem in general, because if someone stops moving, her position does not change, so there is no difficulty in locating her. The tracking system is used to identify who is interacting with particular room components, such as the wall pointing system described below and to direct servo-mounted steerable cameras so they can videotape people as they move about.

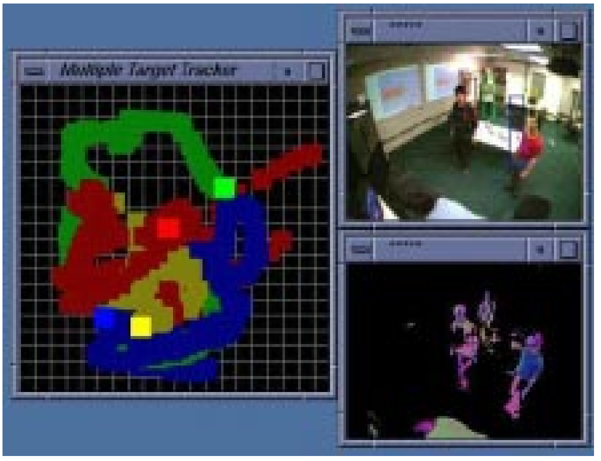


Fig. 2. A debugging window from a three camera, multi-person tracker

To begin interacting with the room, a person would stand in the doorway and say something such as, *"Computer, hello, this is Jennifer."* While the room greets the person, the tracking system builds a color histogram of her clothing so it can determine her identity when she starts moving around the room.

The room has two projected video displays that allow various kinds of pointing interactions. A person can walk up to either of the displays and simply point at something with her finger, e.g. a city on a map, to reference it. This interaction is picked up by a special set of pointing cameras mounted along the surface of the wall. A separate vision system allows a laser pointer to be used in place of a finger. Either pointing system can be used to control a displayed mouse cursor, to write or draw on the wall, or move (i.e. drag) displayed objects.

Through a ceiling mounted camera, the room can also detect when documents are placed on the conference table in order to reorient and blow-up their images for display or OCR. This camera is also used for tracking hand movements over the surface of the table (Dang, 1996). An unusual application of this system is too allow people to assign "functions" to Post-It notes stuck on the table's surface and by touching them communicate with the room.

3.3 Room Control

When the Intelligent Room was in the early stages of it design and construction, the most challenging research problems appeared to be developing its computer vision and speech recognition/understanding systems. What was not obvious is that interconnecting all of the rooms many subsystems and coordinating the flows of information among the room components was a non-trivial problem. Developing a software architecture that allowed the room to run in real-time and cope with vagaries of its real-world interactions emerged to be one of the room's chief research problems.

We developed a modular system of software agents known collectively as the *Scatterbrain* (Coen, 1997a) to control the Intelligent Room. The Scatterbrain consists of approximately 30 distinct, intercommunicating software agents that run on ten different networked workstations. These agents' primary task is to link various components of the room (e.g., tracking and speech recognition systems) and to connect them to internal and external stores of information (e.g., a person locator, the World Wide Web) (Kramer, 1997). Essentially, the Scatterbrain agents are intelligent *computational glue* for interconnecting all of the room's components and moving information among them.

3.4 The Tour Guide Agent

The room's most recent application provides support for someone giving tours of our laboratory. These tours typically involve a group of visitors meeting with a graduate student who discusses and answers questions about the lab's research and shows several video clips. Rather than have these presentations given in an ordinary conference room, we have decided to have them in the Intelligent Room so the room can assist the human tour guide. A typical dialogue between the room and student tour guide is:

Tour guide: "*Computer, load the AI Lab tour.*"
Room: "*I am loading the AI Lab tour.*" Right projector now displays a Netscape browser window with a special Lab Tour home page.
Tour guide: Using hand, points at link to a research project displayed on the wall and says, "*Computer, follow this link*"
Room: Loads the indicated page into the browser.
Tour guide: "*Computer, show me the Intelligent Room home page.*"
Room: Loads the URL corresponding to the name of the page. Then says, *"I have a video clip for this research. Would you like to see it?"*
Tour guide: "*Yes. Show it here.*"
Room: Cues appropriate video casettete to correct position and starts the clip playing on the video display closest to where the person is standing.
Tour guide: (watches video for a few seonds) "*Computer, stop the video. Computer, play the Virtual Surgery clip*".
Room: Performs requested action. Stops video when clip is done.
Tour guide: "*Computer, how many graduate students are there at the AI Lab?*"
Room: "*I am asking the START system for the answer…The Laboratory's 178 members include 17 faculty members, 26 academic staff, 29 research and support staff, and 106 graduate students.*" Also displays web page with elaborated answer.

4 Discussion

An unusual issue with Intelligent Environments is the breadth of research areas they draw upon. Building embedded, interactive systems frequently requires expertise not only in modal technologies such as computer vision and speech understanding, but it also involves substantial development in and places unusual demands on other core AI areas, such as knowledge representation, software agents, machine learning techniques, and cognitive architectures, among others. For example, knowledge representation in these systems can require representing not only the type of abstract symbolic information with which the AI community is already comfortable but also the low-level data from the input modalities in which these systems are grounded. More generally, this requires a collaborative approach to designing all the components of these systems, because, in the end, they must be able to intercommunicate at many levels of abstraction.

4.1 Avoiding Multimodal Nightmares

As with traditional multimodal user interfaces, Intelligent Environments tend to be composed of a wide array of interconnected albeit separate subsystems. Thus, building an IE naturally leads to something of a scavenger approach. An obvious first step is to see what other areas of computer science in general and artificial intelligence in particular have to offer and simply connect extant systems in a modular and piecewise fashion. However, coupled with this is also a strong temptation to simply grab the current state of the art in every field and combine them to get something that quickly becomes a multimodal nightmare.

Intelligent Environments need to be more than a rough assemblage of previously existing systems. Not only do the interactions of the modalities need to be carefully coordinated, but also the intended uses of an IE need to direct what modal capabilities are present from the start. For example, it may well be the case that the input requirements of the environment's applications are actually simpler than what the current state of the art offers, and less complex, more reliable subsystems may be used instead.

This is an essential consideration, because Intelligent Environments free a user from the constraints of a graphical user interface (GUI) only by relying on technology far less reliable than a traditional windowing system. IEs are embedded via audio, speech and visual processing systems that are themselves frequently research prototypes and quite often far less than robust. Imagine for a moment writing a GUI where 20% of the mouse events are actually spurious noise and the some of the complexities of building an IE become clearer.

Hardware systems that use cameras and microphones are susceptible to a wide-range of failure modes. These, in conjunction with algorithmic instabilities in the higher-level software systems that process their outputs, can lead to a wide array of seemingly bizarre or impossible conditions, such as a person appearing to the system to be in two places at once. Visual and speech recognition systems are also fairly tightly constrained with respect to what types of input they are likely to handle correctly. For example, a vision-based multi-person tracker may "lose" people when they occlude one another or blend into the background. These constraints may change unpredictably when conditions such as lighting levels or background noise fluctuate. Ambient light coming through a newly opened door, for example, can completely disrupt a seemingly reliable computer vision system.

There are several ways to deal with these problems. The simplest is to avoid pathological conditions by explicitly forbidding them. While this may be reasonable for a very small number of exceptions, larger numbers put an increasingly unmanageable burden on the user to remember which actions, situations, and environmental conditions are valid. Furthermore, they quickly reduce the entire system to little more than a "toy," useful only for running carefully orchestrated demos. A preferable strategy is to simplify the IE's modalities to the point where they work reliably and coherently with one another. Limited but reliable functionality is a much better thing than sophisticated flakiness.

For example, most of the output of the Intelligent Room's tracking system is frequently thrown away. Most applications don't need and can't make use of real-time trajectory information for the room's occupants. Rather, what is particularly important is to know where someone is when he stops moving, not while he is in motion. Far easier than building a dynamic person tracker is creating a visually-based static person locator that looks for people at rest in places where they are expected to be found, such as sitting on a couch or standing by a display. We are currently construction a new, more reliable version of the Intelligent Room that exclusively makes use of static people locators, rather than a dynamic tracking system.

Even assuming perfect modal processing, interacting with computational objects using human-level phenomena can be difficult and frustrating. For example, because there are not necessarily natural or obvious mappings from the way people express things to functional counterparts in a GUI, a user may exclaim, "That's not what I meant!" even when "understood" correctly by the system. More important than modal processing can be a thorough understanding of how people employ language and gesture and what they mean by them in particular contexts. Knowledge representation is perhaps the largest obstacle in many multimodal efforts. Being expert at recognizing gesture or language is not sufficient; understanding what these things mean in every likely to be encountered context is the hard part, and this is one of the strongest arguments against viewing IEs simply as piecework systems.

Because this mapping between human expression and the capabilities of the system is not seamless, users of multimodal systems are frequently burdened with remembering a great deal of special-case knowledge. This includes: what types of utterances are legal; how particular series of actions (e.g., scripts) are interpreted and processed; and how to artificially manipulate the UI to achieve a desired result. This is problematic because people are not particularly good at keeping track of this special-case knowledge, e.g., how to interact with the system in each typical situation to get it to do something.

Intelligent environments, however, try to avoid this problem from the start by primarily supporting tasks that people would do whether or not there was computational support available for them. We already have natural ways of expressing how to do these activities, because we already do them during the course of an ordinary day. This also provides a clear litmus test for the utility of an IE – do people even bother to use it? Whatever it is being used for could also be done without it and most likely has been up until now anyway.

Acknowledgements

Development of the Intelligent Room has involved the efforts of many people. This includes Professors Tomas Lozano-Perez, Rodney Brooks, and Lynn Stein. Graduate students who have been involved in the room include Mark Torrance, Jeremy De Bonet, Chris Stauffer, Sajit Rao, Darren Phi Bang Dang, JP Mellor, Gideon Stein, Michael Coen, Josh Kramer, and Mike Wessler. Postdocs associated with the project include Kazuyoshi Inoue and Polly Pook. Many undergraduates are also currently working on it. These include Kavita Thomas, Brenton Phillips, Nimrod Warshawsky, Owen Ozier, Marion Groh, Joanna Yun, James Clark, Victor Su, Sidney Chang, Hau Hwang, Jeremy Lilley, Dan McGuire, Shishir Mehrotra, Peter Ree, and Alice Yang.

References

1. Abowd, G., Atkeson, C., Feinstein, A., Hmelo, C., Kooper, R., Long, S., Sawhney, N., and Tani, M. (1996). Teach and Learning a Multimedia Authoring: The Classroom 2000 project. In: Proceedings of the ACM Multimedia'96 Conference. http://www.cc.gatech.edu/fce/c2000.pubs/mm96/c2000.html
2. Black, M. and Yacoob, Y. (1995). Recognizing Facial Expressions under Rigid and Rigid-Facial Models. International Workshop on Automatic Face and Gesture Recognition. Zurich. 12-17.
3. Bobick, A.; Intille, S.; Davis, J.; Baird, F.; Pinhanez, C.; Campbell, L.; Ivanov, Y.; Schütte, A.; & Wilson, A. (1996). The KidsRoom: A Perceptually-Based Interactive and Immersive Story Environment. M.I.T. Media Laboratory Perceptual Computing Section 398. http://vismod.www.media.mit.edu/vismod/demos/kidsroom/kidsroom.ps.Z
4. Cohen, P.R., Chen, L., Clow, J., Johnston, M., McGee, D., Pittman, K., and Smith, I. (1996). Quickset: A multimodal interface for distributed interactive simulation. In: Proceedings of the UIST'96 Demonstration Session, Seattle. 1996.
5. Coen, M. (1997a). Building Brains for Rooms: Designing Distributed Software Agents. In: Proceedings of the Ninth Conference on Innovative Applications of Artificial Intelligence. (IAAI97). Providence, R.I.. http://www.ai.mit.edu/people/mhcoen/brain.ps
6. Coen, M. (1997b). Towards Interactive Environments: The Intelligent Room (a short paper). In: Proc. of the Conference on Human Computer Interaction (HCI'97). Bristol, U.K.
7. Coen, M., Abowd, G., Bobick, A., Cooperstock, J., & Horvitz, E. (1998). Call for Participation: AAAI 1998 Spring Symposium on Intelligent Environments. http://www.aaai.org/Symposia/Spring/1998/sssregistration-98.html#3.
8. Cooperstock, J; Fels, S.; Buxton, W. & Smith, K. (1997). Reactive Environments: Throwing Away Your Keyboard and Mouse. Commmunications of the ACM, 40 (9), 65-73.
9. Dang, D. (1996). Template Based Gesture Recognition. SM Thesis. Massachusetts Institute of Technology.
10. Davis, J. and Bobick, A. (1997). The representation and recognition of action using temporal templates. In: Proc. Computer Vision and Pattern Recognition (CVPR'97). 928-934.
11. DeBonet, J. (1996). Multiple Room Occupant Location and Identification. http://www.ai.mit.edu/people/jsd/jsd.doit/Research/HCI/Tracking_public. 1996.

12. Druin, A. & Perlin, K. (1994). Immersive Environments: a physical approach to the computer interface. In: Proceedings of the Conference on Human Factors in Computer Systems (CHI'94), 325-326.
13. Fitzmaurice, G., Ishii, H., Buxton, W. Bricks (1995). Laying the Foundations for Graspable User Interfaces. In: Proceedings of the Conference on Human Factors in Computer Systems (CHI'95). 442-449.
14. Katz, B. (1990). Using English for Indexing and Retrieving. In: Artificial Intelligence at MIT: Expanding Frontiers. Winston, P.; and Shellard, S. (Eds). MIT Press, Cambridge, MA. Volume 1.
15. Kramer, J. (1997). Agent Based Personalized Information Retrieval. SM Thesis. Massachusetts Institute of Technology.
16. Lien, J., Zlochower, A., Cohn, J., Li, C., & Kanade, T. (1997). Automatically Recognizing Facial Expressions in the Spatio-Temporal Domain. In: Proceedings of the Workshop on Perceptual User Interfaces (PUI'97). Alberta, Canada. 94-97.
17. Mozer, M. (1998) The Neural Network House: An Environment that Adapts to its Inhabitants. Submitted to the AAAI 1998 Spring Symposium on Intelligent Environments.
18. Newman, W. & Wellner, P. (1992). A Desk Supporting Computer-based interaction with paper. In: Proceedings of the Conference on Human Factors in Computing Systems (CHI'92). 587-592.
19. Paradiso, J., et al. (1997). The Magic Carpet: Physical Sensing for Immersive Environments. In: Proceedings of the Conference on Human Factors in Computing Systems (CHI'97), Extended Abstracts, 277-278.
20. Rauterberg, M., Fjeld, M., Krueger, H., Bichsel, M., Leonhardt, U., & Meier, M. (1997). BUILD-IT: a computer vision-based interaction technique for a planning tool. In: Proceedings of the 1997 Conference on Human Computer Interaction (HCI'97). Bristol, U.K.
21. Renomeron, R., Rabinkin, D., French, J., & Flanagan, J. (1997). Small-scale matched filter array processing for spatially selective sound capture. In: Proceedings of the 134th Meeting of the Acoustical Society of America. San Diego, CA.
22. Saund, E. (1996). Example Line Drawing Analysis for the ZombieBoard Diagrammatic User Interface.
http://www.parc.xerox.com/spl/members/saund/lda-example/lda-example.html.
23. Starner, T., & Pentland, A. (1997). First-person perceptual user interfaces through wearable computing. In: Proceedings of the Workshop on Perceptual User Interfaces (PUI'97). Alberta, Canada. 107-109.
24. Stiefelhagen, R., Yang, J., & Waibel, A. (1997). Tracking Eyes and Monitoring Eye Gaze. In: Proceedings of the Workshop on Perceptual User Interfaces (PUI'97). Alberta, Canada. 98-100.
25. Torrance, M. (1995). Advances in Human-Computer Interaction: The Intelligent Room. Working Notes of the CHI 95 Research Symposium, May 6-7, Denver, Colorado.
26. Want, R., Schilit, B., Adams, N., Gold, R., Petersen, K., Goldberg, D., Ellis, J., & Weiser, M. The ParcTab Ubiquitous Computing Experiment. Xerox Parc technical report.
27. Weiser, M. (1991). The Computer for the 21st Century. Scientific American, September, 94-100.
28. Wellner, P. (1991). The DigitalDesk Calculator: Tangible Manipulation on a Desk Top Display. In: Proceedings of UIST'91. 27-33.
29. Wilson, A. & Bobick, A. (1998). Recognition and Interpretation of Parametric Gesture. Submitted to International Conference on Computer Vision (ICCV'98).
30. Zue, V. (1994). Human Computer Interactions Using Language Based Technology. IEEE International Symposium on Speech, Image Processing & Neural Networks. Hong Kong.

A Room of Your Own: What Do We Learn about Support of Teamwork from Assessing Teams in Dedicated Project Rooms?

Lisa M. Covi, Judith S. Olson, Elena Rocco

Collaboratory for Research on Electronic Work (CREW)
The School of Information
The University of Michigan
701 Tappan Street
Ann Arbor, MI 48109-1234
Email: [covi, jsolson, rakele]@umich.edu

William J. Miller, Paul Allie

Steelcase, Inc.
P.O. Box 1967
Grand Rapids, MI 49501
Email: pallie@steelcase-research.com

Abstract. To inform the design of groupware technologies such as those for cooperative buildings, we investigated the work habits of teams that collaborate in dedicated project rooms. We conducted field work that included interviews of teams in 9 U.S. companies who had dedicated project rooms and a 6 week observation of one site. In our study, team members using dedicated project rooms reported clear advantages: increased learning, motivation, and coordination. Our findings suggest that cooperative buildings need to support important features of collocated teamwork such as flexible shared visual displays and awareness of team members' activities.

Keywords. cooperative buildings, computer supported cooperative work, CSCW, groupware, teamwork, space

1 Introduction

Cooperative buildings, dynamic physical environments that support collaborative social interaction, incorporate groupware to support teamwork within and between physical structures. Despite increasing availability of groupware for face-to-face and remote collaboration, we have a less than adequate knowledge of what teams actually need and how they work. There clearly is a need for groupware: more and more companies are organizing their work into teams (Becker *et al.*, 1995), more of these teams are not collocated (Kinney *et al.*, 1996) and companies are experimenting with alternative officing to save real estate costs (Robertson, 1996). However research indicates that teams struggle to stay coordinated when they are not collocated (Olson *et al.*, 1996), and they reject groupware which ignores requirements for teamwork (Orlikowski, 1992).

What do teams actually need? We know that teams need to communicate and share documents. Some groupware, like desktop videoconferencing, chat windows, voicemail, e-mail, and Notes discussion databases, support communication among people who are either remotely located (same time, different place) or need to converse asynchronously (different time, same place and different time, different place). Other technologies support document sharing: screen sharing software for same-time work, file transfer protocols and Notes databases for asynchronous work. However the slow diffusion of these technologies suggests that perhaps we don't know the whole story yet. Research investigation has focused more on technology for remote collaboration than on assessing needs for collocated teamwork. Teams still need to collaborate face-to-face (same time, same place).

How can we learn more about teamwork? Our research team decided to investigate what one might think of as the ideal setting for communication and collaboration: teams collocated in a dedicated project room. We were interested in collecting descriptive data on the configuration of dedicated project rooms, the work practices of teams working in dedicated project rooms, and analyzing reports of team members to discover the relationship between these rooms and teamwork. We were also interested in how companies and teams assessed the value of dedicated project rooms and how groupware might be designed to replicate or improve the advantages of dedicated project rooms when teams are not able to collocate. To explore these issues, we went to the field. We interviewed managers and team members. We also observed work practices in dedicated project rooms and other special facilities in 9 companies who indicated to us that they had project rooms. One of these sites allowed us to do in-depth observation and interviews of a group that used a dedicated project room for the 6 weeks they worked on a special project.

Our expectations about the value of dedicated project rooms and the kinds of features that will support successful teamwork came from studies of distributed cognition (Hutchins, 1995). We knew from these studies that there are two important sources of group information: *cognitive artifacts* in use, which codify procedures and make the project's progress visible, and *behavior* of team members, which models work practices and cues task coordination. Dedicated project rooms make both of these sources handy. We also expected that the major rationale for corporations to assign a team to a dedicated project room would be time savings, especially for groups using specialized artifacts because dedicated project rooms reduce time loss from setting up and tidying the room. Our investigation of the activity in these rooms gave us insight into important details in the design of future groupware.

2 Findings: How Dedicated Project Rooms Support Teamwork

In order to identify important work practices and factors which influence them, we investigated how dedicated project rooms were being used in real companies. The Fortune 500 companies were a mixture of manufacturers, service providers, and consultancies. Out of 14 dedicated project room, seven were "live-in," meaning the team members had no other offices. In each of the 9 companies, we interviewed either the Chief Information Officer (CIO), the Facilities Manager, or the Manager of a team working in a dedicated project room. Where possible, we interviewed team members in the dedicated project room.

The second kind of field study was an in-depth study of one 8-member group that resided in a dedicated project room as part of an intensive software development training experience. In this case, we administered a short survey to the 8 team members before and after the project, and observed the group at work in several sessions each week totaling about 5 hours a week for 6 weeks. We photographed the progression of artifact use in the dedicated project room and adjacent work areas. In addition, we conducted 60 minute semi-structured interviews at the end of the 6 week period. Due to the sensitive nature of project work, we were unable to audiotape or videotape groups at work or interviews.

2.1 Types of collaborative spaces

In addition to the live-in and not live-in dedicated project rooms, the companies we visited showed us a variety of spaces that were used for collaborative activities (Table 1). They showed us creative arrangements of cubicles that opened onto a large conference table, making an easily accessible "project area" or group commons. In addition, they showed us meetings rooms that were owned by a particular group. The owned meeting rooms were very accessible for use by the group, but because they were not dedicated to a particular project, the group could not leave their project artifacts in this space. There were also various meeting rooms shared among groups via different scheduling schemes. Many of these rooms did not even have computers or projection technology.[1] We also toured training rooms (typically outfitted with 10-15 computers and a projection device), special purpose video conference rooms, hotelling and motelling arrangements[2], and cafeterias used for meetings outside of mealtimes.[3]

---

[1] Most conference rooms had nothing but tables and chairs in them.

[2] We discovered that the distinction between hotelling and motelling is the amount of advanced reservation required, and how much work the "concierge" would invest in setting up your phone forwarding, your files (kept in movable file cabinets in a storeroom), and your name on the door. Clearly, the service is better in the "hotel" but the costs are higher.

[3] Where interruptions from passers-by wishing to socialize are minimized by having a small sign on the meeting table announcing that this was a meeting, implying that visitors were not welcome.

The live-in project rooms we saw were larger than a typical office, usually about 16’ x 20’, housing from 3 to 6 people. The not live-in project rooms were similar sizes and could conceivably serve more people, since crowding and interruptions could be alleviated by retreating to one’s office.

	Live-in Project Rooms	Not Live-in Project Rooms	Group Areas with Commons	Owned Meeting Rooms	Scheduled Meeting Rooms	Video Conference Rooms	Cafeterias used for Meetings	Training Rooms	Totals
TireCo	2	1		1	4			1	9
Big50Co		1			5			2	8
Consult-ingCo	1		most		2+	1		1	6+
MicrochipCo			1				1		2
Older ComputerCo	1			2					2
SoftwareCo		1	most	many	many		1		5+
ApplianceCo	1	3	many	many	many	1	1	2	11+
Younger Computer Co	1	1		1	1				4
AutoCo	1					1			2
Totals	7	7	4+	5+	14+	3	3	6	49+

Table 1 Types of Collaborative Spaces by Company Pseudonym.

2.2 How teams obtain and inhabit dedicated project rooms

Corporations are struggling with the counter-forces of efficiency and cost of real estate. Nevertheless, the companies we visited still assign some teams dedicated project rooms in spite of the increased cost of additional or specialized collaborative space. Who gets these rooms? We expected from the literature that the major driver for assigning groups to dedicated project room would be efficiency. In live-in dedicated project rooms, in particular, all team members are collocated and communication overhead is minimal. Artifacts are present and shared, and team members are available. Also, new team members have the opportunity to learn quickly because they can witness all the behaviors that go into this team’s performance, making it easier to acculturate.

Indeed, managers reported that one main driver for giving a team a dedicated project room is efficiency. But, of course, not everyone gets a project room because not all teams do the kind of work that can benefit from a project room (they do parallel, deep analysis without the need for constant coordination), and real estate is costly.

There were two chief patterns in which dedicated project rooms were allocated and utilized. Several live-in project rooms, were given to teams who were behind on a critical development project. In the spirit of Skunk Works (Rich *et al.*, 1994), the idea is that if people are put into a room, released from other bureaucratic impediments, they will be both creative and efficient. For groups in trouble, the hope was that they could succeed if they just lived together. It was a signal from management as to both the importance of the project and the desperation that management felt, a last ditch effort. These rooms were configured such that the individuals worked facing the walls on the periphery and the center of the room contained a table or common work surface for scheduled or impromptu meetings (Fig. 1a, 1b). Communication between team members was easy and efficient in these rooms and team members' work was closely coupled with one another (discussed further below). These rooms seemed to bustle with activity, bulge with artifacts and appear rather untidy.

The second pattern for room use was related. Management gave dedicated project rooms to prestigious groups needing room for private conversation, or to groups whose importance they wanted to signal via committment of resources. We will call these not live-in project rooms "war rooms." In U.S. corporations, the term war room can mean several types of rooms. A war room can be a control center for monitoring late-breaking data for network operations services (Bucholz, 1996) or financial services (Gandy, 1995). However, the term war room is also used to mean an executive meeting room where sensitive decisions about human resources or project strategy are made behind locked doors (Downs, 1994). These rooms often served as "show rooms" with furniture, lighting and carpeting signaling the importance of work accomplished in this room to the participants. These rooms were configured as "board rooms" with participants sitting around a large central table and technology available for presentations (Fig. 1c). Team members faced each other rather than walls and individual work areas. When not in use for meeting with a full group, these rooms served as "thinking space" for group members who had access to these secure areas. Even if the room had a telephone for audio conferencing, team members reported that they would not forward their telephone to the room and segment group activity from other responsibilities not related to the team's work.

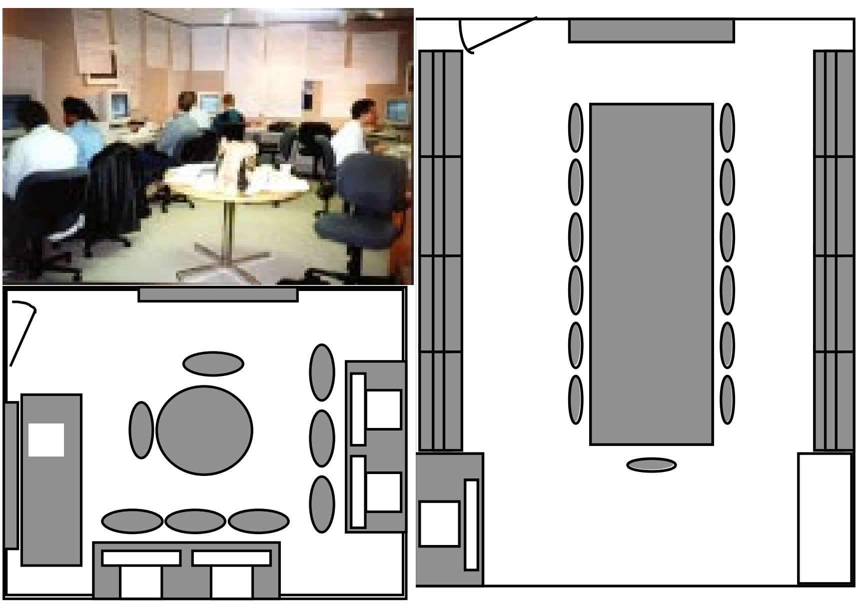


Fig. 1. a.. Photo of "skunk works" at YoungerComputerCo (top left) and. floor plans for b. TireCo (bottom left) and c. "war room" at ApplianceCo (right)

It was interesting, too, to contrast the rationales given us by different managers. CIOs repeatedly pointed to expected efficiency and their need to get the job done. On the other hand, facilities managers, who reported to the Chief Financial Officer, were more interested in justifying the costs of these rooms, since they are typically rewarded for reducing their budgets. Managers of the team in the dedicated project room reported prestige as the major driver. The different types of managers were merely responding to their incentive schemes, a point made salient by Orlikowski (1992).

2.3 How cognitive artifacts support teamwork

Because of the importance of cognitive artifacts in the literature on distributed cognition (Hutchins, 1995), we were particularly interested in the use of the shared artifacts and the interactions with the other team members. A number of artifacts were used in these rooms, artifacts that one rarely sees in shared meeting rooms. Table 2 lists the kinds of display artifacts and number of rooms containing them by type of room: skunk works (live-in dedicated project rooms), war rooms (not live-in dedicated project rooms and all collaborative spaces we toured (for comparison).

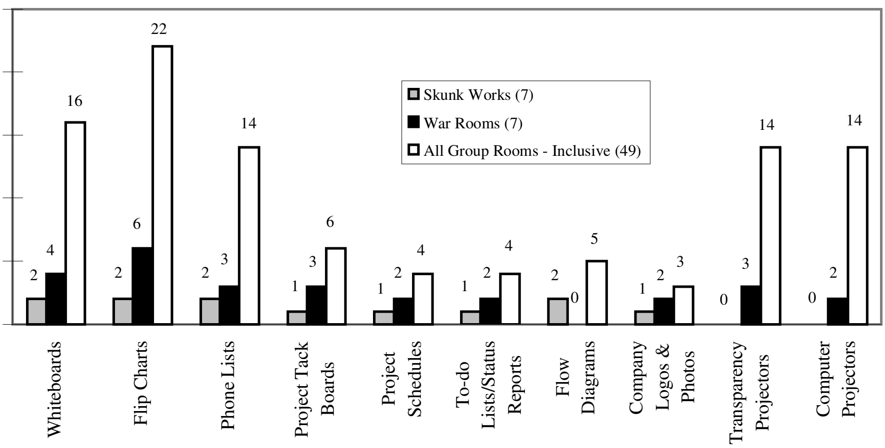


Table 2. Ten different types of shared visual display artifacts, comparison of number of rooms containing them by type of room

Shared Visual Displays. Flip charts, whiteboards, tack boards and walls often held important artifacts, displaying work in progress, current status of tasks, reference materials or past accomplishments. These shared visual displays helped the team make intangible work visible and editable via representations. These representations help facilitate desirable social interactions.

For example, in the skunk works of our intense case study site, 41 flip chart sheets appeared on the walls at all times. These flip charts were co-authored by the group (they were requirements for the software they were building) and clustered, moved, and edited at various times in the production of the software (Fig. 1a). Individuals who were later coding parts of the software moved these near their workstation and referred to them often (Fig. 2b). And, in early analysis of how to architect the system, use cases were displayed side by side so that developers could see the similarities, in the hopes of finding useful abstractions.

At another site, a war room used by human resource people had the two opposing long walls covered by rolling whiteboard panels mounted on three parallel tracks such that three layers could be viewed in turn (Fig. 2a). These panels contained an elaborate organizational chart which consisted of 1" x 4" magnets linked by narrow electrical tape. Each magnet represented a manager from that company and listed the person's name, background highlights, affirmative action category and a small photograph. Career paths of managers were planned in this room, a task that has to take into account not only the history of the individual but also the balance of talents across the organization. The complexity of the task was well served by the enormity of this single visual display. Team members also reported that when making decisions about moving people within the company, they would take the magnet representing a manager *in hand* and contemplate a career path. The act of holding the magnet reminded them of the weight of their decision, the change in the organizational chart created materiality for the decision and the photograph on the magnet helped them recall the importance of their decision for this person and those affected by an organizational move.

Another war room contained three full walls of tack boards. The room was used by a business strategy group who used the room to host high-level meetings on projects concerning the future of the company. The tack boards held a wide variety of display artifacts. The team members mounted past presentations slides (hard copy of an electronic presentation) in clear plastic sheet protectors with Velcro backing on one third of the tack boards. Supplemental detail data on different parts of the presentation were printed on 8.5" x 11" sheets and tacked to the wall. There was also work-in-progress displayed and annotated with sticky notes. However, the most popular display feature of this room was the computer projection system which they used to develop ideas via a scribe at the in-room computer. Team members felt that a key feature of this technology was the ability to argue at the projected display rather than at each other. By focusing discussion on the representation of the work rather than at a disagreeing team member, they felt that they could better able to resolve differences and move on with the work.

Coordination Documents. Besides making work visible and editable, cognitive artifacts also facilitated coordination. For example, the software development team constructed a to-do list consisting of objects to be built, the team member responsible for building each object, and tick marks as objects were completed. More items were added to this list as new objects were discovered. These lists provided immediate reference for coordinating individual tasks and provided a ready check of the current status of the project. Similarly, action items were used in several collaboration spaces for reminding team members of agreed-upon team obligations and priorities for which they were accountable (usually for the "next" meeting). These artifacts helped team members keep track of where they were individually and with respect to project deadlines. Other teams left telephone logs, which allowed team members to see who had already been contacted on projects that involved telephone support, telephone surveys or client contact. Some teams posted vacation schedules and office telephone numbers.

Motivation Tools. We were surprised that dedicated project rooms contained a wide variety of motivational artifacts which were specific to team identity and relationship to the company. In one project room, planning principles (similar to Demming principles and standard methodology) were posted on the wall. Elegant flow charts depicting the sequence of projects or processes communicated a sense of belonging and importance of the group in key production activities (Fig. 2c). The team we studied in depth had company logos and photographs extolling the power and speed of the products and employees of this company. One rapid response team had three copies of a motivational poster that reminded them of the value of rapid teamwork, one copy per wall, viewable from anywhere in the room.

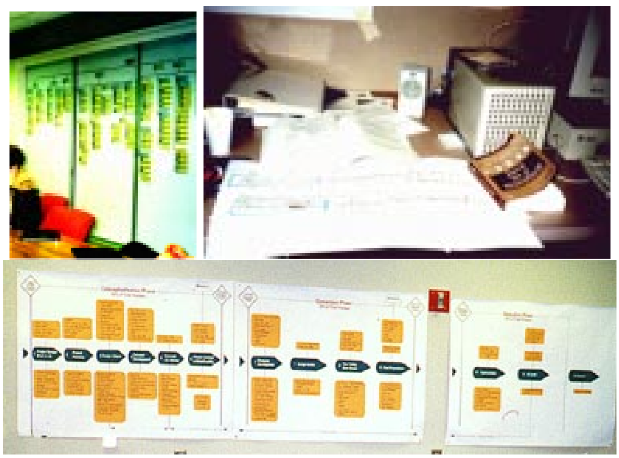


Fig. 2. a.. Magnetic organizational chart (top left), b. Flip chart on desktop (top right), and c. Project flow chart (c. bottom)

2.4 How collocation supports teamwork

Besides facilitating interactions via artifact-sharing, dedicated project rooms also facilitate interactions between team members due to collocation. In skunk works, the team members were in constant contact with each other during working hours since they had no other offices. In war rooms, where team members have other offices, full team presence was less common. However, when a deadline approached, team members primarily resided in the war room. Collocation provided a number of advantages for teamwork, including awareness, implicit training, easy transitions from individual to group work, and motivation.

Awareness. One skunk works housed an emergency response team who help sales people broker deals concerning various pricing and packaging options for important customers. Team members had desks about 15 feet apart. They reported that collocation provided team awareness. They were close enough to overhear other team members' conversations *if they chose* and note for future reference what customer was involved, which sales person called, what kinds of deals were offered and who offered the appropriate deal. Similarly, when the call volume increased for an individual assigned to a particular product line, team members could cover for each other. As often happens among administrative support people who work near each other on similar tasks, merely paying attention to the general level of activity can promote impromptu help-giving without explicit negotiation.

Similarly, in the software development training skunk works, both students and trainers worked in the room together. Collocation allowed the trainers to easily move from one student another. Because trainers could see over students' shoulders, they could monitor progress over time, intervening when necessary.

Implicit learning. Awareness supports teamwork in a learning environment through explicit instruction and monitoring. Implicit learning also supports teamwork in a dedicated project room through learning by example. People imitate each other when they are collocated. For example, team members reported that they learned "how things are done," how to make requests on the phone, and how to chart progress by observing and replicating the behavior of proximate others. This phenomena is an important component of organizational learning, the acquisition of team-based routines that make an organization run smoothly (Cohen *et al.*, 1994). Many people merely call this learning "on the job."

Easy transitions from individual to group work. Most teamwork involves different styles of work in different stages (Olson *et al.*, 1992). At some stages it is important for the team to collaborate, typically, in a meeting (e.g., making joint decisions or planning a project). At other times, team members need to work individually and in parallel (e.g., analyzing a problem, proposing rationale for re-organization, or producing code). Transitions between individual and group work may be influenced by many factors such as size of the group, nature of he work, availability of places in which to meet, urgency, diversity of individual team members, group leadership in addition to proximity. One of the reported advantages of private offices with walls and doors was the ability to signal when the occupant was available (door open) or unavailable (door closed).

The prevalence of meetings in many work settings and delays in projects when team members are not available, attests to the belief that focused collaboration works best in the same time and same place. Although more investigation is necessary to determine the precise conditions for each stage of work, we know that team members reported that being co-present during *individual* work provided opportunities for interruption at a moment's notice for important interactions. However, they also indicated that interruptions sometimes disrupted the flow of individual work. Our evidence suggests that providing enough distance between individual work areas and defining explicit team norms for use of the team space may help team members negotiate the conflict between individual and group work styles.

Motivation. It is well known in the social psychological literature that team members will instill each other with motivation, either positive or negative (Forsythe, 1990). A phenomena called "Social facilitation" occurs in small teams when observable enthusiasm and drive catches on and the entire team works hard (Allport, 1920). In larger groups, however, it is equally likely that individuals, seeing others work hard, decide they are extraneous and will engage in "social loafing" (Williams *et al.*, 1981). In the skunk works, shared motivation was reported as positive and contagious.

3 Implications for Technology Support of Teamwork in Cooperative Buildings

Dedicated project rooms support teamwork in many ways. Collocation with cognitive artifacts and team members offers the broadest bandwidth for cooperative work. Teams develop shared documents together thus making intangible work visible, editable and more carefully considered. Cognitive artifacts also include documents for team coordination, and motivation tools to remind teams of their identity and importance. Collocation increases awareness of individual contributions, provides opportunities for impromptu help-giving, and allows sharing of team members' work practices. In dedicated project rooms, team members implicitly learn from one another through organizational routines and make easy transitions between individual and group work. Collocation helps team members motivate each other through social facilitation when teams are small. What implications do these findings have for creating innovative work environments with information and communication technology such as "cooperative buildings?"

The predominance of shared visual displays in dedicated project rooms suggests that technologies which support the creation, editing and persistence of flexible documents are essential for coordination. However, a review of current groupware technologies reveals a gap between how teams use coordination technologies and how teams use shared displays. Applications like Lotus Notes and project planning software provide appropriate diagrams and lists for coordinating work. But unlike posted flip charts and whiteboard lists, screen representations do not remain visible in a single shared format to individual team members during work. Having a single shared visual display provides ready reference to coordination information by a simple glance rather than, for instance, loading a World Wide Web home page or viewing an electronic document by launching an application.

Currently, there are some computerized technologies which provide shared visual display. However, the features of these systems are primitive when compared to the flexibility and variety of shared displayed artifacts we found. Some good examples of display technology are Xerox's LiveBoard, Microfield Graphics Softboard, and Smart2000's board. These products provide large visual displays and allow more than one person to work together to create a shared representation via a pen-based interface. They offer advantages over same-time, same-place technologies because the penstrokes are stored electronically and can be viewed remotely. However, they only accommodate about one-screen's worth of displayed information[4] and do not cover the field of view such as wall-sized whiteboards or tack boards which we found at several study sites. Although some of these electronic representations can be printed on flip chart-sized paper, using the display technology in this manner is expensive and awkward.

We also found another feature of shared visual display that team members reported as being important but difficult to create electronically. For example, in the human resource war room, although we might imagine projecting a wall-sized, editable organizational chart, it is harder to imagine utilizing magnets or sheets of paper with such a display. Designers of cooperative buildings might consider how teams would use information appliances that could serve the role of the magnets in this setting. Tangible artifacts with electronic codes could index more attributes of the people represented on the 1" x 4" magnets such as career history, records of rationale for moves and alternative moves considered like a design rationale (Moran *et al.*, 1996). Decision-makers could still interact with material objects while experimenting with secondary electronic representations for documenting decisions or evaluating outcomes.

Cooperative buildings should provide facilities for both remote and collocated teams because some advantages of collocation are difficult or impossible to reproduce for remote and asynchronous work.. Despite experimentation with simulated collocation, we don't yet have the interaction bandwidth that exists in dedicated project rooms. Some examples are MediaSpace, which linked 25 or 30 offices through videocameras and monitors (Harrison *et al.*, 1997) as did Bellcore's Cruiser (Fish *et al.*, 1993), Sun's Piazza (Isaacs *et al.*, 1996) and EuroPARC's Rave (Garver *et al.*, 1992). The ClearBoard prototype captured details of not only the shared work but of the details of the co-worker's attention (where he is looking before he acts) (Ishii *et al.*, 1992). These technologies are not only expensive, but there are serious questions about whether they indeed duplicate awareness, fruitful interruption or the sense of "being there." Heath and Luff (1991) found that co-workers connected by video had to behave in an exaggerated way in order to produce a reaction. To support remote work in cooperative buildings, we need to know whether and how to integrate remote video to support different types of teamwork.

Designers of cooperative buildings should also consider how technologies support tightly-coupled versus loosely-coupled teamwork. Our findings suggest that collocation, rather than geographical distribution is best for tightly-coupled work Field studies elsewhere have shown that, given the limitations of current groupware, team members who are separated from the majority of their team members participate less in collaborative work and decrease their coordination with the rest of their team. (Olson *et al.*, 1996). The remote team members reorganize the work so that it requires less coupling. They do not benefit from awareness, implicit learning or motivation that collocation supports. The design of cooperative buildings provides a valuable opportunity to enhance the advantages of collocated teamwork and explore new technologies to extend these advantages for remote teamwork.

[4] Although they have the dimensions of a whiteboard, because the pixels are relatively fat, electronic visual displays cannot hold as much information as a whiteboard.

Acknowledgments

This paper was strengthened by the comments of David O'Leary and from anonymous reviewers. We are grateful to Steelcase, Inc. for support of this work. We also acknowledge our corporate sites for their cooperation in this endeavor, many of which were part of the Information Systems Executive Forum at the University of Michigan Business School. At CREW, Stephanie Teasley contributed by interviewing at two key sites.

References

1. Allport, F. H. (1920). The influence of the group upon association and thought. Journal of Experimental Psychology, 3 , 159-182.
2. Becker, F., Quinn, K., & Tennesen, C. (1995). The ecology of collaborative work. Cornell University International Workplace Studies Program technical report.
3. Bucholz, C. (1996). Inside the War Room. Telephony, 231 (13), 28.
4. Cohen, M. D., & Bacdayan, P. (1994). Organizational routines are stored as procedural memory: Evidence from a laboratory study. Organizational Science, 5 (4), 554-568.
5. Downs, A. (1994). Who controls your company's war room? Training, 31 (5), 105-109.
6. Fish, R. S., Kraut, R. E., Root, R. W., & Rice, R. E. (1993). Video as a technology for informal communication. Communications of the ACM, 36 (1), 48-61.
7. Forsythe, D. R. (1990). Group Dynamics. Brooks/Cole Publishing Co., Pacific Grove, CA.
8. Gandy, T. (1995). War of the Screens. Banker, 145 (831), 78-79.
9. Gaver, W., Moran, T., MacLean, A., Lovstrand, L., Dourish, P., Carter, K., & Buxton, W. (1992). Realizing a video environment: EuroPARC's RAVE system. In: Proceedings of the Conference on human Factors in Computing Systems (CHI'92), ACM Press, New York. 27-35.
10. Harrison, S., Bly, S., Anderson, S., Minneman, S. (1997). The Media Space. In K. Finn, A. Sellen, S. Wilbur (Eds.): Video Mediated Communication. Lawrence Erlbaum Associates, Mahwah, NJ, USA. 225-244.
11. Heath, C., Luff, P. (1991). Disembodied conduct: Communication through video in a multi-media office environment. In: Proceedings of the Conference on Human Factors in Computing Systems (CHI'91), ACM Press, New York. 99-103.
12. Hutchins, E. (1995). Cognition in the Wild. Cambridge, MA: MIT Press.
13. Isaacs, E., Tang, J. C., & Morris, T. (1996). Piazza: A desktop environment supporting impromptu and planned interactions. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'96), Cambridge, MA.: ACM Press. 315-324
14. Ishii, H., Kobayashi, M. (1992). ClearBoard: A seamless medium for shared drawing and conversation with eye contact. In: Proceedings of the Conference on Human Factors in Computing Systems (CHI'92), New York: ACM Press, 525-532.
15. Kinney, S. T., Panko, R. (1996). Project teams: Profiles and member perceptions: Implications for group support system research and products. In: Proceedings of the 25th Hawaii International Conference on Systems Science (HICSS'96). New York: ACM Press.
16. Moran, T. P., & Carroll, J. M. (Eds.) (1996). Design Rationale: Concepts, Techniques and Use. Mahwah, NJ: Lawrence Erlbaum Associates.
17. Olson, G. M., Olson, J. S., Carter, M., & Storrøsten, M. (1992). Small group design meetings: An analysis of collaboration. Human Computer Interaction, 7, 347-374.

18. Olson, J. S., & Teasley, S. (1996). Groupware in the wild: Lessons learned from a year of virtual collocation. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'96). New York: ACM Press. 419-427.
19. Orlikowski, W. J. (1992). Learning from Notes: Organizational issues in groupware implementation. In: Proceedings of the Conference on Computer Supported Cooperative Work (CSCW'92). New York: ACM Press. 362-369.
20. Rich, B. R., Janos, L. (1994). Skunk Works. Boston, MA: Little, Brown, and Company.
21. Robertson, I. (1996). Hoteling: The miracle cure to reduce space. KLR Consulting, Inc., 4 (2).
22. Williams, K. B., Harkins, S., & Latane, B. (1981). Identifiability as a deterrent to social loafing: Two cheering experiments. Journal of Personality and Social Psychology, 40, 303-311.

Experience in Building a Cooperative Distributed Organization: Lessons for Cooperative Buildings[T]

Geraldine Fitzpatrick[2], Simon Kaplan[1,2] and Sara Parsowith[1]

[1]CRC for Distributed Systems Technology (DSTC)
[2]Department of Computer Science and Electrical Engineering
The University of Queensland
St Lucia 4072, Australia
Email: s.kaplan@dstc.edu.au
URL: http://www.dstc.edu.au/wOrlds/

Abstract. This paper discusses a three-year experiment to build a distributed research group, equipped with state-of-the-art computing facilities, spread over three cities in Australia. Despite the provision of the sorts of facilities to be expected in cooperative buildings, such as high-speed networks and videoconferencing, significant synergy (i.e., closely-coupled collaborations) among the distributed subgroups did not develop. This was not only due to the problems of distance, but was exacerbated by several political and organizational issues. An important lesson is that successful 'cooperative buildings' will depend not just on the technology but also on an appropriate managerial, organizational and political climate in which these resources can be meaningfully exploited. The paper outlines the experiment, discusses why synergies did not emerge, and points to implications for cooperative buildings and design paradigms based on the notion of pattern languages.

Keywords. cooperative buildings, locales framework, social worlds, cooperative work, distributed workgroups, serendiptious interactions, organisational structure, patterns

1 Introduction

The development of 'cooperative buildings' will afford new possibilities for people to work and play together at a distance. These affordances will be based around com-

[T]This work has been supported by the US Defense Advanced Research Projects Agency (DARPA) under grants F30603-94-C-0161 and F30602-96-2-0264 administered by the US Air Force, and by the Cooperative Research Centres Program through the Department of the Prime Minister and Cabinet of the Commonwealth Government of Australia. The views and conclusions expressed in this document are those of the authors and should not be interpreted as representing the official policies, expressed or implied, of the Defense Advanced Research Projects Agency or the U.S. Government. We would like to thank the members of IEU for their openness, assistance and friendship during the course of this study.

puting, networking and advanced user interfaces. Examples of such advances include:

- Members of a distributed design group work together to evolve the design of a complex artifact, using a combination of physical and virtual media;
- Grandparents talk and play with their grandchild from their house half a continent away;
- A manager moves from room to room talking to members of his group. The building tracks his location using signals from his mobile phone. His computer workspace is continually ready-at-hand;
- Joe notices Bill in his San Diego office, 'leans over' from Sydney and initiates a discussion.

Traditionally, buildings housed groups of some kind – organization, division, firm, family, department. In the examples outlined above, the notion of 'group', 'organization', 'family' being housed within a single building falls down. In future a distributed group spread around a network of smart, cooperative buildings might well come to see themselves as being in 'the same' location[1]. Although the buildings and groups are physically distributed, the practical impact of the affordances built into the cooperative buildings will be to break down or eliminate the barriers of distance[2].

We believe that the very notion of cooperative buildings must co-evolve with learning to take advantage of new affordances. It is possible, for example, to conceive of a cooperative building not as physically bounded by the external skin of a physical building, but rather as a virtual entity that could potentially span (parts of) several, widely distributed physical buildings.

But it is unlikely that technology alone will bring about this change. In 1994 an experiment began in Australia to build a distributed, but integrated semi-commercial research group, the Internet Exploration Unit. This group spans three cities, groups and sites from two different organizations, and shares a common purpose, viz. investigating how to deal with resources (particularly information) on an internet-wide scale. The groups had access to advanced computing resources, many of which are of the type we might expect in cooperative buildings, such as high-speed networks, video-conferencing and a range of computing hardware. However, three years later we can clearly see that closely-coupled inter-group synergies did not develop, although there was some degree of black-box sharing of prototypes.

We believe there are some interesting lessons from this case for the emerging cooperative building community. In essence they underline the importance of organizational, political and sociological factors in the success of distributed workgroups – factors that are well-known from the CSCW community (Grudin, 1988)– and point to the need to consider the application of technological advances in the context of their use. We contend that technology alone won't make smart buildings work – it is the

---

[1] Or adjoining locations… notions of 'the same place', 'adjoining place', etc., will change radically.

[2] There is another way of thinking about cooperative buildings that need not have anything to do with distributed groups – rather they have to do with the notion of having the virtual artifacts and media needed for work 'ready-at-hand' through ubiquitous, embedded computing systems and interfaces. This kind of use should be taken as implied when reading this paper.

creation of the appropriate organizational and sociological context within which to deploy these technologies that will make the difference.

To discuss this case study and its implications for cooperative buildings, the paper is structured as follows. Section 2 introduces some analytical preliminaries, while Section 3 tells the tale of our case study. Section 4 then draws some implications for the design of cooperative buildings and points to possible design paradigms, based on Alexander's notions of pattern and pattern language (Alexander, 1977).

2 Analytical Preliminaries – Social Worlds and Locales

Before discussing the study itself, we first introduce the Locales Framework used in its analysis. The Locales Framework (Fitzpatrick, Kaplan *et al.*, 1996) evolved to address the problem of how to account for complex dynamic domains of work, both physical and virtual, and the design of cooperative systems to support/augment work in such domains. The framework is based on three key notions. The first is that actions and interactions are continually evolving; the emergent situated nature of work is therefore a central premise. The second is that social worlds are the prime structuring mechanism for interaction. A social world is a group of people who share a commitment to collective action, bounded by the limits of effective communication. These first two notions are drawn from Strauss (Strauss, 1993). The third notion is that people creatively use and evolve any available features of a domain to get their work done. There are currently five high-level aspects to the Locales Framework. While presented as if distinct, they are in fact highly interdependent and overlapping, each providing a different perspective into the life of a social world. They should be used by the designer as a sensitizing, rather than prescriptive, analytic device. The five aspects are:

Locale foundations: There are two components of locale foundations. The first is to identify the social world of interest and its associated members, rules, roles, conventions, group processes etc. The second is to identify the locales or places the members use to get their work done. This includes the inherent features of the domain, and the relevant artifacts, tools, resources, work objects, etc. (Cooperative buildings can be seen as providing the places and resources for social worlds.)

Civic structures: Civic structures looks to understand the social world of interest and its locale in a global context. Hence it is about identifying other related social worlds and locales, and understanding the relationships, interactions and influences among them. For example, this is where external influences such as organizational, legislative, professional, political etc., can be considered, as well as the issue of how social worlds emerge and dissolve.

Individual views: This aspect accounts for the fact that groups are made up of a heterogeneous collection of individuals. Each individual will likely have their own view of the group locale based on their current level of interest or involvement. Further, each individual will probably belong to multiple social worlds and work on many different tasks at once, with varying and shifting degrees of intensity. They are likely to maintain an idiosyncratic view across some collection of locales, dynamically negotiating varying levels of focus and participation.

Interaction trajectory: Trajectory looks at all the temporal aspects - past, dynamically emergent present, and imagined future, the rhythms and cycles, etc., - of the group's locale and its associated people and entities. In understanding the social world and its members in action, we hope to understand how the locale of work and civic structures enable and constrain the moment-by-moment doing of work.

Mutuality: Mutuality draws explicit attention to the possibilities for, and actualization of, presence and awareness in a locale for the purposes of maintaining a sense of shared place and action. Awareness refers to the information about any entity, person or object that another entity chooses to focus upon. For example, can you see who is working on a task? What they are doing? What is the current state? With what degree of granularity? Presence is the reciprocal of awareness and concerns the aggregation of personal information (identity, functional and interactional possibilities, current activity etc.) that an entity makes available to the shared place of work.

3 Our Experiment: The IEU Social World

As we indicated previously, the Interaction Exploration Unit (IEU – all proper and organizational names are pseudonyms) was set up as a joint project over three sites, with two major organizations involved. Several technological affordances were put in place to support interaction among the members of the two groups, videoconferencing, and a high-speed ATM network was also promised. However, these groups did not form a synergistic whole, although each of the groups independently was both productive and successful. To understand why, we begin by employing a social worlds-based description of the IEU and its activities.

Our groups of concern are Tony, Mike and Zak from Future Generation Systems Centre (FGSC) and Adam, Scott, Gail and Rita from the Scientific Research Group (SRG). Tony is the nominal project leader, while day-to-day leadership of the group is split between Tony in Brisbane from FGSC and Adam in Melbourne from SRG.

We focus on a nine-month period starting about 2.5 years into the life of the IEU. Visible and successful collaboration among the teams and team members was seen as critical and the team members felt under pressure to improve their collaborations after an unofficial management directive. Until this time, in effect the major strand holding the two groups together were funding and reporting requirements, together with a loose shared interest in common research issues. We started a qualitative study of this group because we are interested in CSCW in action, knew this group had significant technological affordances at their disposal, and were interested to see how, and what kinds of, collaborations emerged.

3.1 IEU civic structures

Several other social worlds have an impact on or interest in the operation and success of the IEU. Examples include the organizations that contribute resources (funding, equipment and additional seconded staff) to the project, the standards bodies to whom IEU members Tony and Zak contribute, and other social worlds within FGSC and SRG. For example FGSC runs a major research integration project, and this depends in part on IEU producing leading-edge tools, concepts and systems that they can use in their integration effort. Furthermore the peer communities of other researchers who meet at scientific meetings and overlap with IEU membership also form social worlds that may have some influence on, interest in, or relationship with IEU. The civic structures identified here ultimately played a significant role in fostering certain collaborations and discouraging others.

3.2 IEU locales and their resources

The FGSC and SRG personnel of IEU are physically distributed across three cities spanning approximately sixteen hundred kilometers across Australia. Space at the FGSC is at a premium. Zak, Mike and a visitor share one office, while Tony and other visitors share the other room. Each person's space consists of a desk, workstation, bookshelf, notice board and telephone. There are also shared white-board and shared bookshelves. In the SRG office in Melbourne, Adam and Gail have adjacent office spaces separated by partitions. Scott has his own closed office on the other side of the floor. Rita works on her own in Sydney, roughly halfway between Melbourne and Brisbane.

Their shared virtual locales both within and across sites consist of a number of different technologies. Each full-time person has access to email and postal mail as well as the telephone. A range of group information is available via WWW pages, which Tony is diligent in maintaining. All three sites have dedicated video-conferencing machines. These are in Zak and Mike's room at FGSC, and in a separate meeting room at both SRG sites. Obviously, when all the members gather for a workshop, the workshop location becomes a shared physical locale for the duration of the gathering. The Internet, which provided email, web and other facilities, ran to each member's desktop. Unfortunately, the installation of the ATM network was greatly delayed by factors outside the control the IEU, FGSC or SRG, and was never realised.

It became evident that the physical separation of work locales had a significant impact on mutual availability. This in turn hindered the emergence of new collaborations and is in contrast to physical co-location or close-location; being temporally and spatially close-by means that people have easier access to the conversations and activities of others should they choose to.

3.3 Summary observations of the IEU trajectory

As it happened, no strategic cross-group collaboration came about during the nine-month course of the study. More interestingly, though, the FGSC members of IEU became involved in a significant collaboration with people from other FGSC units during this same time period, a collaboration of the type that was desired between FGSC and SRG. We will return to this later. However there were numerous instances of other smaller scale collaborations both between and within IEU sub-groups.

As a group, significant effort was expended to try to facilitate closer collaboration between the FGSC and SRG members of IEU. Prior to the directive being given, cross-site collaboration mainly involved Tony and Adam. Although all members of the group had access to telephone and fax, direct and group email, and the WWW as a repository of shared group information and shared tool access, they rarely used them. After the directive, Tony and Adam established a weekly group videoconference between Melbourne and Brisbane, and a fortnightly session between Brisbane and Sydney, so that people could become more familiar with each other's work.

After some months of this, they also held a 2-day workshop to develop a coherent research strategy for the next twelve months. While the workshop did result in a shared vision of an abstract system architecture, it failed to identify clear points of collaboration between individual projects. The researchers returned to their separate work sites and continued working on their own projects. The workshop did, however, lay the foundations for exploiting future collaborative opportunities and for members moving their work in line with the architecture.

3.4 A potential collaboration

Two months later, a promising opportunity was identified during one of Tony's visits to the Melbourne site. He was explaining to the group at SRG what Mike was planning to do back at FGSC in the next work period when Adam realized that he was essentially working on the same issue from a different angle. Adam had already known from the videoconferences that Mike was looking at this particular issue but had never understood why.

Over the next few months there were various contacts between Mike and Adam to explore their common interests. This primarily consisted of discussing and documenting a common abstract model of the problem domain. Adam wrote a draft document explaining his ideas. Through email, Mike made constructive comments on the model. Adam would then revise the model, and more email discussion would follow. Occasionally they talked by phone. If they had been able to complete the work, Adam wanted to institute a system of regular phone calls. Mike however preferred email for more technical discussions because he felt he was able to contribute more after having time to reflect on his responses rather than give off-the-cuff responses on the phone. However a promising opportunity was lost when SRG management abruptly moved Adam away from IEU to another (competing) SRG project.

3.5 Collaboration in practice

While collaborations at the scale or level of strategic importance wanted by management did not emerge, or failed to progress when they did emerge, there were many other instances of ways in which members of IEU worked together on smaller, short-term or less-strategic scales. The following vignettes give a flavor:

Co-Management, cross-sites, assigned: Tony and Adam worked closely together especially for the major reporting and strategic planning activities required of the unit. They tried to phone each other twice a week at pre-set times, co-authored documents using the web as a shared document repository, and acted as the conduits for much of the information passed on to the rest of their on-site colleagues.

Paper co-authoring, cross-sites, emergent: Rita and Gail, both SRG employees but in different cities, worked together to write a conference paper, and Gail installed Rita's prototype tool. They recognized a potential overlap of interests when they had an opportunity to talk face-to-face at the workshop. At Gail's instigation they wrote a paper exploring these ideas, having decided on a structure and allocated sections to write. Though the paper was subsequently rejected, they gained a much deeper understanding of each other's work and Gail later started to integrate Rita's prototype with her own. However, their work together was stalled when both were given non-IEU work by their SRG management.

Working together on a shared project, same room, mix of assigned/emergent: Zak and Mike, sharing the same room, worked closely together on a particular project. In the early stages and whenever technical details had to be worked out, they would use the white-board between their desks. They also used the white-board to write up the project goals and task allocations. When the work was settled enough to be divided into parts, their interactions tended to be around larger granularities of work, such as the review of a draft document. Occasionally they used email for project issues. Now that they are working on separate projects, they no longer use the white-board for shared work-related notes and both keep their own private to-do lists.

One develops, another uses, cross-site, assigned: Scott developed a tool in Melbourne and Mike was asked to install it in Brisbane so that FGSC staff could test it. Mike ran into lots of problems while trying to install the tool and, after various attempts, gave up as he found the task too difficult. He moved on to other projects and the prototype remained uninstalled, particularly as it was critical to no-one's work in Brisbane. However, towards the end of the study a new IEU employee needed Scott's prototype for a new contract and, with remote help from Scott, eventually managed to get it installed. This was typical of successful cross-group collaboration: interaction at the interface of prototypes rather than communal work on a shared problem.

3.6 Romany: An emergent collaboration that worked

An interesting contrast to the above study is an emergent cross-unit collaboration within FGSC called Romany, which evolved over the same period in which the FGSC and SRG members were supposed to be finding ways to work together more closely.

Rather than being imposed or suggested by management, Romany grew up as a grass-roots initiative involving people from IEU and two other units of FGSC. A lecturer with West University, a partner of FGSC, and his researcher Susan were both associated with another FGSC unit, but worked in a separate building to FGSC on the same campus. They had taken on a masters student to investigate a particular research project. For some time previously, Zak from IEU had also been thinking of a distributed object approach to a related problem.

It was only after Susan mentioned the Masters thesis to researchers at IEU/FGSC during an informal visit that Zak and Susan started to talk together and evolve a more generalized definition of the problem and its potential solution than both of their original positions. Around the same time there was also a growing awareness in the larger international research community of the potential roles for the kinds of systems FGSC constructs. Susan posted a description of their approach to an international mailing list, and was inundated with expressions of interest. Not long after, Susan, Zak and some other members of IEU attended a workshop at which many of the same people from the mailing list were present. They spent a lot of time talking to people and, given the level of interest, the Romany project to implement their ideas was born.

At FGSC, Zak is the person nominally designated as working on this problem. In practice many other researchers from several units of the FGSC actively work with him. They have established their own internal mailing list which also includes many others at FGSC interested in the problem but only able to make a sporadic contributions to the work because other constraints. After some period of discussion, the core group gathered together for a one-day internal workshop to scope the work. Some of the peripheral members were also able to drop in for short periods.

Following on from the workshop, a draft document was written. The ideas continued to evolve at regular face-to-face meetings. After each meeting, as summary was posted to the Romany web site, forming the basis for the following period's work and discussions at the next meeting. Zak anticipates that they will release a stable document once some revisions are complete. This should stimulate a further round of discussions with the international community, as well as prototype products and standards contributions, all of which are highly valued outcomes at FGSC.

3.7 Discussion

Why was the Romany initiative so successful when IEU attempts to create collaboration were comparatively less so? We briefly summarize some explanations here:

Grass roots evolution. The Romany initiative grew up in a grass-roots way on the part of the researchers. Although they had complementary interests, they found common ground and ways to support each other. The IEU collaboration was imposed top-down, existed in a competitive environment (between SRG and FGSC, and between researchers), and although the researchers shared common general aims it was hard to form and sustain networks of dependence among the members of the group.

Defined goals. The Romany group had fairly well defined, shared, short-term goals which evolved over time. IEU had shared interests but goals were individual, and substantial articulation work to try encouraging the emergence of shared goals was generally unsuccessful.

Organizational support & culture. FGSC members involved in Romany received active support from their management, in terms of diversion of resources to the project. This is in line with the culture at FGSC that encourages synergistic, relatively stable research groups. SRG, on the other hand, encouraged more individual research with highly opportunistic redirection of staff from project to project to meet their own commercial goals. A source of many of Tony's management problems within IEU arose from the conflicting organizational and political cultures in FGSC and SRG, especially in the interpretation of their relative commitments to group outcomes as defined by the major funding body.

Personal motivation. Romany involvement was personally motivated, whereas IEU involvement was directed from the top. SRG employees are permanent government employees, so their jobs are secure, whereas FGSC employees are all employed on 'soft money'. Ironically this seems to encourage the FGSC and its researchers to take a focused, longer-term view whereas the SRG researchers tend to have a more individualistic shorter-term view. This dissonance in motivation was another source of conflict within IEU.

Long lead-time. Romany germinated over several years in Zak and Susan's minds before more direct discussions led to it becoming a coherent project. The corporate activities of FGSC encouraged this evolution. The effective collaborative activities of IEU also took a long time to emerge. In this kind of research environment, forcing collaboration is problematic.

Stable core membership. The membership of FGSC is fairly stable, while SRG management moved staff around and reassigned researchers in response to short-term contingencies. Lack of continuity of social world membership discouraged the growth of research programs in any case, and the effects of distance exacerbated this.

Understanding the details. The close physical location of the Romany researchers encouraged the discussion of the rationale and details of work from which opportunities for collaboration were recognized. Several smaller collaborations also emerged from the workshop because of a similar understanding of details. However, the interactions between IEU sites, e.g., via email and formal video-conferencing sessions tended to encourage only high-level overviews.

Key advances face to face. While they used a variety of media for communication, key advances in the evolution of Romany were made via serendipitous or easily arranged face-to-face interactions. Similar patterns were also found in the IEU collaborations that were co-located. However, face-to-face encounters rarely occurred between the remote IEU projects.

Technological support. For the Romany group, technology was used to support physical interactions in a secondary capacity, using phones, email and the web. The case is similar for the co-located members of IEU. For the distributed members of IEU, technology was their primary source of interaction. This imposed restrictions on the styles of interactions that were possible between sites. It also imposed dissonances that were difficult to overcome, such as differences in the ways that the technology was used, either by personal preference or other constraints.

4 Implications for Cooperative Buildings

We turn now to drawing some implications from our study. We focus first on how space and culture shaped the IEU and Romany projects, and generalise from there to organisational implications more generally. This leads to a discussion of how we might conceive of designing cooperative buildings in the future.

4.1 Drawing out the lessons of the study

The major lessons of the study are that, while Romany – from a research perspective – 'worked', IEU didn't. By 'worked' here we mean that spontaneous, meaningful collaboration grew up among the individual researchers, and blossomed. We believe that Romany worked for a number of organisational and spatial (building-related) reasons, and that IEU failed for the same reasons. In our minds the two projects are almost flip sides of the same coin when viewed from this perspective.

There are several fundamental reasons why Romany succeeded: The organisational culture encouraged the organic growth of new projects; the spatial arrangements of the participants facilitated their interaction; communication media afforded rich and varied styles of interaction; and there was the right mix of complementary research interests. Romany started almost entirely serendipitously, from chance meetings in hallways and coffee-room discussions. The proximity of the West Uni researchers, and the physical layout of FSGC headquarters in Brisbane, with its tightly-packed, intimate rooms, close location of different groups, and shared kitchen/coffee spaces, created a climate where this kind of interaction could flourish. Various levels of involvement were also encouraged because of the ease of 'dropping in'.

IEU, on the other hand, while experiencing similar phenomena locally within the sub-group based within FGSC in Brisbane, did not experience the same kind of growth of new, exciting, 'bottom-up' projects that spanned sites. The same reasons apply, but in reverse. This time, there were significant organisational barriers, imposed by problems between FGSC and SRG. There were differences in culture between FSGC and SRG – FSGC encouraged close, team-type research projects, SRG's culture discouraged such exercises. Spatially, FSGC researchers are packed together encouraging interaction, SRG's IEU researchers are isolated in individual. The virtual media employed – formal videoconference meetings, email – were insufficient to overcome the lack of other means for serendipitous and informal interaction such as coffee-room encounters. Interestingly enough, when IEU did establish a face-to-face environment, during their workshops, there were signs that this situation might improve, but organisational barriers prevented effective follow-through.

What has this to do with cooperative buildings? There are two ways to consider cooperative buildings – as a work environment enhanced with improved affordances for local work – this is the advanced war-room or trading-room model – or as a family of affordances built into the building to help overcome the negative effects of distance. A cooperative building could, of course, do both. Clearly it is the latter that has our focus in this paper. The point for cooperative buildings is to support richness and variety in social interactions. In particular, serendipity, informality, and easy availability to one another have a critical part to play in stimulating interaction among users of a building.

4.2 Services and space in cooperative buildings

Winston Churchill once said “There is no doubt whatever about the influence of architecture and structure upon human character and action. We make our buildings and afterwards they make us. They regulate the course of our lives” (cited Brand, 1995). Our study brings out how Romany evolved because of the physical and organisational ‘shape’ of the FSGC, and how IEU failed to achieve long-distance collaboration because of failures of organisational shape, and the absence of meaningful substitutes for the lack of physical shape. It is the latter problem that we could have expected a cooperative building to overcome.

Of particular importance to us are the ways in which buildings provide services, and the ways in which the spatial layout of a building helps shape organisational interaction. The latter helps foster informal, serendipitous interaction, ambient awareness of what ‘the other users in your space are doing’, and so on, while the former is crucial to the development of cooperative buildings.

For example, the FGSC space is well-equipped with almost-ubiquitous power and network points, and a well-designed networking infrastructure, making services freely available wherever needed. Space is, as we have noted, at a premium, so groups tend to be crammed into very tight quarters which creates an intimate environment well-matched to an organizational culture encouraging experimentation. Interestingly, when a new service was added – ISDN for the videoconferencing – only one service point was installed in one of the IEU offices. The resulting lack of flexibility, compounded by the general lack of space at the FGSC, made using the videoconferencing system for anything but occasional formal meetings impossible.

Cooperative buildings have the potential to radically alter the ways in which services and space interact and support organisations. Indeed, Brand (Brand, 1995) points to ways in which this is already happening, as advances of computer and networking technology require that buildings need complete rewiring for communications every few years. Cooperative buildings change the nature of services quite directly. They require the introduction of new services – such as large-wall displays, active-badge networks, stations and cells for wireless networks, more power points, more data points, increased wiring in conference and meeting rooms as well as open-plan and individual office spaces. They change the consequences of the evolution of services. For example, a large-wall display surface is a new kind of service, but using it changes the nature of the space into which it projects – interactions between changes to services and changes to space become enmeshed.

Cooperative buildings warp the nature of space. If one wall of my office is a large-screen display, permanently videoconferenced to your office across the continent, to a large extent these two rooms ‘become the same space’ (Dourish and Bly, 1992). There are a myriad of implications of this – limitations of space, structure and site can be overcome by enhancing the services properly, management can extend their organizational reach, groups can form and re-form more easily, with less spatial reorientation. But this assumes a level of sophistication in the services well beyond what is possible at the moment. Our studies – and common sense – point to the continued need for co-location, at least for some periods of time, as an essential element of intimate interaction.

4.3 Designing from the sociology to the structure: Applications of pattern languages

However, by far the biggest implication of our study is the overriding importance of social and political factors. This implies that we should conceive of cooperative buildings from the needs of the buildings' occupants. In a well-designed building, the needs of the users initially shape the space appropriately. Over time, as Churchill pointed out, the space then reshapes the users. In a cooperative building, even in their current nascent form (regular buildings with networks), we should rephrase this as: In a well-designed building, the needs of the users initially shape the space and services appropriately.

One possible way to design from this perspective is to look to design techniques that treat social issues and needs equally with structural and construction needs in building. We contend that the Locales Framework can give us a way of deconstructing and understanding the structure and dynamics of organisations and groups, thereby providing us with a powerful tool for identification of critical issues and problems. To carry this through to design, we believe it would be hugely profitable to draw on Alexander's work on patterns and pattern languages.

Alexander developed the notion that any building is constructed from a collection of patterns. These can be thought of as idioms of design and construction that capture the essence of a certain aspect of, e.g., a room, building, street or neighborhood. Individual patterns can be combined to form pattern languages that can in principle be used generatively as a formative part of the design and construction process (Alexander, Silverstein *et al.*, 1975; Alexander, Ishikawa *et al.*, 1977; Alexander, 1979).

A pattern is a solution to a problem in a context. Grounded in practical experience, a pattern should articulate a problem, a context in which that problem arises, and a solution in that context. One of Alexander's famous patterns concerns Alcoves. The problem here is that, while family members like to interact together and be close, they also like privacy and need space for individual activities. The solution is to design communal living space so that it contains a collection of alcoves, which can be used by family members for private activities while not withdrawing completely from family activities. Note that the pattern captures the essence of a design idea but does not prescriptively indicate how to realize it (although suggestions or example can be offered as part of the pattern) – patterns should be used interpretively. Note also that the captured essence is to do with a social phenomenon and possible solutions through arrangement of space and services that ease the burden, not directly with physical layout. This is typical of almost all of Alexander's patterns.

The concept of pattern languages has also been applied to other domains, for example, organisational structure and dynamics (Coplien, 1995). Coplien's pattern language identifies ways of ensuring that software development organisations work as seamlessly as possible. One of Coplien's famous patterns – Conway's Law – points to problems with communications breakdowns in software development organisations whose organisational structure and product architecture are not well-aligned, and suggests ways of reorganising to reduce these impedances. Again, note how an organisational, social problem, is the issue, and the pattern identifies ways of reshaping to overcome the problem.

Recall that a pattern is a solution to a problem in a context. We suggest (and studying Coplien and Alexander bears this out) that the 'problems' are almost invariably social or interactional. Further, we believe that the problems identified in these pattern languages are invariant. Changing from physical to virtual space, introducing new technologies, or any of the other technological affordances of cooperative buildings will not change these problems or make them go away. What might change is the solutions. For example, Alexander's solutions are almost all cast in terms of ways of conceiving of structuring space, Coplien's in terms of structuring organisations. It's possible that, as we move to cooperative buildings with richer services, some of the solutions will change, but the problems never will. For example, several of Coplien's patterns suggest physical relocation of groups to improve communication and remove problems; in a cooperative buildings universe, other solutions to do with changing communications services might solve these problems equally well.

We believe that a synthesis and reinterpretation of these different pattern languages can lead to a powerful, abstract model capturing the essence of the critical issues in the design of cooperative buildings in the future. As pattern languages are of necessity based in experience, this is a hypothesis that we will attempt to prove in the next several years.

5 Conclusions

Although blessed with a substantial nugget of advanced communications and collaboration technologies, the IEU failed to build a meaningful, synergistic, distributed group structure, degenerating instead into several smaller, independent units. The reasons for this are mostly organizational and political rather than a reflection of failures of the technologies alone. We believe there are salutary lessons in this for the cooperative buildings community. No one will ever use a co-operative building for its own sake. Rather, advanced constructions of this kind will be taken up because they afford significant advantages to their user communities. It behooves us to ensure that we take serious account of how we facilitate this along with the evolution of the buildings themselves. The question of how to design cooperative buildings to do this remains an open one. However we suggest that the kinds of approaches and sensitivities to social and interactional issues as driving forces that Alexander pioneered in his work on pattern languages and design processes are the basis for a fruitful beginning.

References

1. Alexander, C. (1979). The Timeless Way of Building. New York: Oxford University Press. Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I., & Angel, S. (1977). A Pattern Language - Towns, Buildings, Construction. New York: Oxford University Press.
2. Alexander, C., Silverstein, M., Angel, S., Ishikawia, S., & Abrams, D. (1975). The Oregon Experiment. New York: Oxford University Press.
3. Brand, S. (1995). How Buildings Learn: What Happens After They're Built. New York: Penguin.
4. Coplien, J. O. (1995). A Generative Development-Process Pattern Language. In: J. O. Coplien, & D. C. Schmidt (Eds.), Pattern Languages of Program Design. New York: Addison-Wesley Publishing Company. 183-237.
5. Dourish, P. and Bly, S. (1992). Portholes: Supported awareness in a distributed work group. In: ACM Proceedings of CHI'92. ACM Press. 541-547.
6. Fitzpatrick, G., Kaplan, S. M., & Mansfield, T. (1996). Physical spaces, virtual places and social worlds: A study of work in the virtual. In: CSCW'96. Boston, MA.: ACM. 334-343.
7. Grudin, J. (1988). Why CSCW Applications Fail: Problems in the Design and Evaluation of Or-ganizational Interfaces. In: ACM Proceedings of the Conference on Computer Supported Cooperative Work. Portland, OR.: ACM Press. 85-93.
8. Strauss, A. (1993). Continual Permutations of Action. New York: Aldine de Gruyter.

The Kumamoto-Kyoto-MIT Collaborative Project: A Case Study of the Design Studio of the Future

Susan Yee, William J. Mitchell

Massachusetts Institute of Technology
School of Architecture and Planning, Department of Architecture
77 Massachusetts Avenue, Room 7-231, Cambridge, Massachusetts 02139, USA
Email: syee@mit.edu, wjm@mit.edu

Ryusuke Naka

Miyagi University
School of Project Design
1 Gakuen, Taiwa-cho, Miyagi 981-32, Japan
Email: naka@mail.sp.myu.ac.jp

Mitsuo Morozumi

Kumamoto University
Faculty of Engineering, Department of Architecture and Civil Engineering
Kurokami 2-39, Kumamoto City, Japan 860
Email: moro@arch.kumamoto-u.ac.jp

Sigeyuki Yamaguchi

Kyoto Institute of Technology
Faculty of Engineering and Design, Department of Architecture and Design
Goshokaidou-cho, Matsugasaki, Kyoto City, Japan 606
Email: shige@ipc.kit.ac.jp

Abstract. The Department of Architecture at the Massachusetts Institute of Technology has conducted a series of experimental design studios, as part of a larger ongoing research endeavour called The Design Studio of the Future, an interdisciplinary effort focusing on geographically distributed computer-mediated design and work group collaboration issues. A recent exploration was a collaborative design project joining geographically dispersed design students, faculty, researchers, and practitioners from Kumamoto University, Kyoto Institute of Technology, and MIT to examine the nature of computer networked collaborative environments and advanced computer-aided design technologies to support architectural education and practice. This paper will describe this project, which provided the students and faculty members with practical experience in the use of emerging technologies for collaboration, design, and communication in both the day-to-day activities of distributed groupwork as well as in the more formalized reviews.

Keywords. architectural education, collaborative design environments, computer-mediated communication, geographically distributed design, social process of design, teamwork, telecommunications, virtual design studio

1 Project Overview

The Kumamoto-Kyoto-MIT (KKM) project, a five week virtual design studio conducted in the summer of 1996, was one in a series of explorations forming the ongoing research of the MIT Design Studio of the Future. The Design Studio of the Future project is an interdisciplinary effort between the School of Architecture and Planning and the School of Engineering focusing on geographically distributed electronic design and work group collaboration issues that are important in establishing prototypes of innovative design environments. These environments are ones in which the aggregation, sharing, and understanding of intellectual resources and expertise from a diversity of people, places, and disciplines act as a major factor in a collaborative design process. The KKM project provided an experience of working in such a prototypical design environment.

The KKM Project joined geographically dispersed design students, faculty, researchers, and practitioners from Kumamoto University, Kyoto Institute of Technology, and MIT into a virtual design studio established through the Internet. Precursors to such a virtual design studio, in which design participants distributed across space and time collaborated, communicated, and prepared joint design proposals in an electronic environment, include projects as early as a 1991 studio between design students at the Graduate School of Design at Harvard University and the School of Architecture at the University of British Columbia (Wojtowicz *et al.*, 1995), projects more recently at MIT, and studios at the University of Sydney (Maher *et al.*, 1995) among others.

The intent of the KKM Project was to explore, through experience, not only issues of collaborative design work, but also the social nature of a computer-mediated design environment forming a distinctive design community with existing and emerging telecommunications and computer-aided design technologies.

1.1 The design problem

The framework for the design problem for the KKM studio was established through the design requirements for an actual project for the Kumamoto ArtPolis ‘96 International Architectural Exhibition. Kumamoto ArtPolis is a group concerned with the creation of architectural works that demonstrate and accentuate the cultural heritage of the region.

The KKM studio's task was to design an urban structure for the exhibition, an "ArtStation", on a vacant site adjacent to the Kumamoto Castle. The project was conducted as a competition where the ideas from the winning scheme would be used for the realization of the actual structure by Koji Yoshii, the designer originally given the commission, for the exhibition in November of 1996.

1.2 The participants

The participants of the project included nine graduate students, three from each location, who were the designers of the project. Also involved was a team of design faculty members, researchers, graduate students, and practitioners who acted as design critics, technical support, and advisors. The challenging task of this diverse group was to work together on a common design project despite differences in location, time, language, and culture.

1.3 The technological tools used for design communication and design collaboration

The KKM project used synchronous and asynchronous technologies for collaboration within the virtual studio. Because of the large time difference between the sites, asynchronous communications, such as electronic mail and the postings of images, CAD data, and text on the World Wide Web (WWW), were heavily used. The WWW was the central "place" of the digital studio. It initially served as a database for displaying design information for communal access. Subsequently, it became the medium for communication where design material in a variety of forms, including text, sketches, images, video, CAD models, and digital renderings, were presented and transferred for elaboration. Lastly, at the end of the project, the site on the WWW became a knowledge-base; it represented the collective design knowledge, impressions, and speculations of possible design instances for the project, including the winning scheme. It was with this design knowledge-base that the final physical construction was conceived (Fig. 1).

For synchronous communications, video conferencing technologies were employed (Fig. 2). We used the PictureTel system over ISDN lines for the more formalized intermediate and final reviews making a connection with all members of the project. The set-up was based on past virtual design review experiences at MIT (Shelden *et al.*, 1995).

For the informal sessions, the participants used CUSeeMe to meet with their colleagues. During all these synchronous sessions, the home pages on the WWW formed the backbone of the discussion. Timbuktu was also used as an application sharing tool to connect the participants and the design material being developed at the different sites. These technologies provided the building blocks for the virtual studio space.

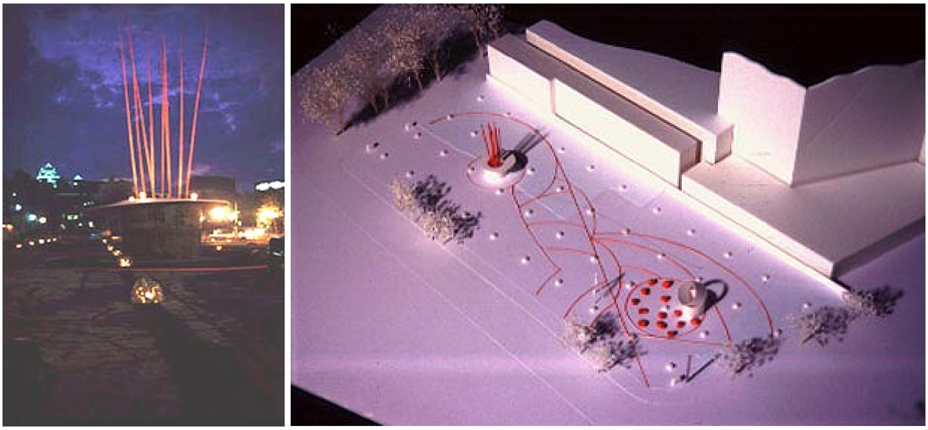


Fig. 1. Final ArtStation; photo and model.

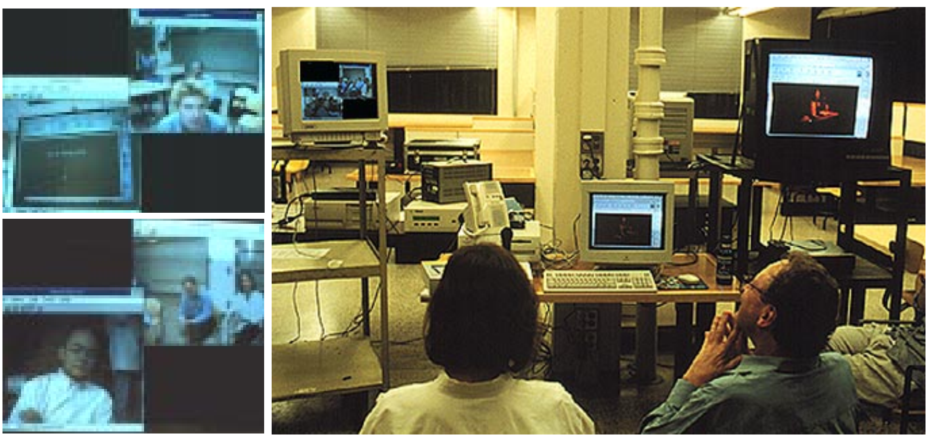


Fig. 2. Video conferencing at final review at MIT.

1.4 The organizational structure of the design collaboration

The participants were organized into three design teams, with one member from each university. This kind of organizational structure was established to encourage distributed collaboration and cross-fertilization of design ideas between the members of each site. This organizational format not only maximized the need to utilize telecollaborative tools during the entire design process, but it provided a means of sharing local expertise about the site and the city of Kumamoto. Because the program required a deep understanding of the project's site and an intimate knowledge of the culture, each team's participant located in Kumamoto was the essential place-based liaison for his virtual teammates whose only notions of the physical site were through images, computer graphics, video, and written and verbal impressions, all contributing to a kind of simulation of the actual site.

The design teams were formed by nominations of the students themselves. We used video conferencing sessions prior to the start of the project for some informal introductions and general inquiries about the nature of the design of the structure. These inquiries, together with photos, video, and CAD models of the site, were assembled on a webpage. In the first week, the nine designers used this database of information about the project to develop individual ideas for the design. This type of introduction to the studio was used to encourage the designers to quickly leap into spatial concepts about the monument early in the design process. The students placed their initial ideas on individual webpages for a group review.

This collection of webpages (Fig. 3A) and the intellectual resource it represented created a type of "marketplace" of design ideas forming the basis for understanding the design orientations of each participant. The students, through this presentation, were able to prioritize their nominations for potential teammates. Although it was the final act of the advisors who matched team members by grouping compatible design ideas displayed on the individual webpages, taking into consideration the students' choices, we may imagine the possibilities of computational agents helping in this process of team formation.

Fig. 3. A. "Marketplace" of individual webpages for team formation. B. Example of a team webpage.

Once the three design teams were formed, each team was asked to nominate members to fulfill certain team coordination tasks in addition to their design responsibilities. These roles included a team webmaster (WM), a team minutes-taker (MT), and a team schedule coordinator (SC). These coordination-oriented functions were distributed between team members and location. Fig. 4 summarizes our process of team formation and assignment of sense-maker roles.

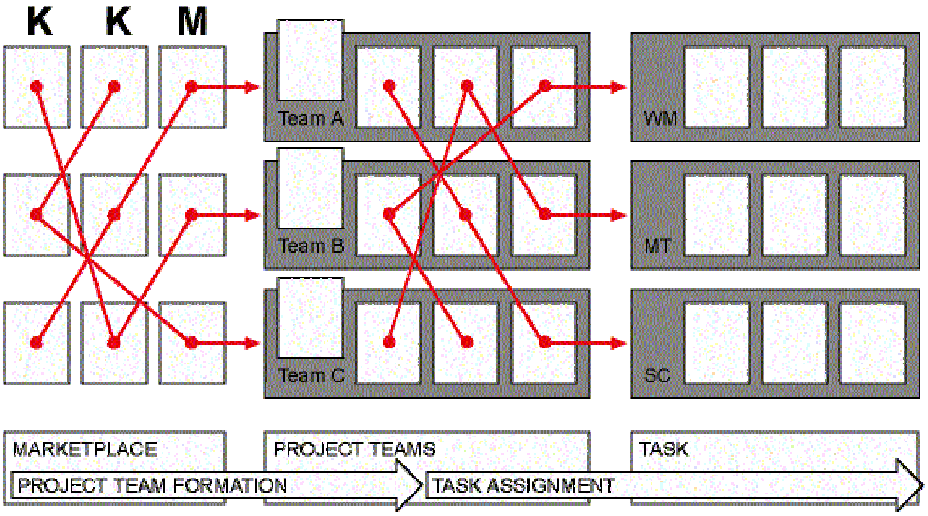


Fig. 4. Team formation and task assignments.

The team webmaster had the task of constructing and maintaining a team webpage (Fig. 3B) for use in the team presentations. This page served as a consensual document which illustrated the development of ideas and designs produced by the collaboration. It also linked to the individual webpages, or personal digital sketchbooks, maintained by each team member.

A second member of each team was the meeting minutes-taker, who recorded the proceedings of team meetings and discussions, both synchronous and asynchronous, between team members and design critics. The third member was the schedule coordinator who would determine the need for and coordinate the times of team meetings, ensuring effective communication between the sites.

Although these roles seemed time-consuming and mundane, they were important in establishing a common understanding of the development of the design as well as in the making of a coherent presentation to the critics. All the roles needed an intimate connection to the team's process of design and the designed artifact. The webmaster's page construction was designed to reflect and communicate the overall architectural idea. The minutes-taker was forced to interpret the concepts and comments of his colleagues. This activity helped to highlight misunderstandings and ambiguities of both natural language and architectural language. The schedule coordinator had to understand both the collaboration process and the design progression to be effective.

These roles were used to bring to light and to help ease the often complex and confusing issues of collaboration within design teams.

Although the design teams approached the collaboration aspect of the project in slightly different ways, all of the teams did consider their design as a truly collaborative effort, in that they all attempted to amalgamate each team members' idea to form a single overall concept. This predominate mode of collaboration may be considered "single task collaboration", where "the resultant design is a product of a continued attempt to construct and maintain a shared conception of the design task. In other words each of the participants has his own view over the whole design problem and the shared conception is developed by the "superposition" of the views of all participants" (Maher *et al.*, 1996).

Once this "shared conception" was grounded within the team's design idea, other collaboration techniques were used to stimulate innovative design development. One team divided up the design concept into parts, such as the structure, materiality, and landscaping, and delegated these parts to each member for in-depth investigation for a limited amount of time after which they would regroup and share their findings. Another team used a relay approach where the entire design was passed from one member to another for elaboration. The member with the design would act as master designer for a limited time period. The proposal would be evaluated and then passed on to the next designer. These collaboration techniques were successful because there existed a consensus on the overall architectural concepts.

2 Interweaving Collaborative technologies with Social Practices: Some Preliminary Observations

Throughout the design project, the designers showed remarkable skill and speed in their appropriation of the collaborative technologies for their group work processes. During this studio and others we have conducted, the original premise was to emulate actions and interactions traditionally found in place-based studio work; in effect, they were investigations on how collaborative technologies can be adapted, altered, or matched to existing design practices. Frustration and innovations occurred when incompatibilities were found between the existing collaborative technologies and the communication activities in which we actually engage in order to convey design ideas. This emulation is important in developing new features and functions of technologies that may be customized to particular design communication and collaboration needs. However, in addition to this flow of examination, we should also consider the notion that no technology is value-free and that we are affected by the technologies that we use. This symbiotic relationship between technologies and social practices in design environments encourages the idea that critical re-evaluations of actions and interactions within the social process of design, from the organizational and social structure of a studio to the conventions for communicating design ideas, may be as important as, if not more important than, the development of the technologies that actually support these new practices.

Included below are some preliminary observations from particular examples of the KKM project which may give some initial insights to both the types of technologies desired and the types of practices fostered by telecollaboration.

2.1 Adapting technologies to collaborative processes

The electronically distributed design studio required the students to not only negotiate their positions on design issues, but also to determine the most effective means to communicate these ideas in a timely fashion through telecommunications. We begin to see some of the characteristics of collaborative tools desired by designers in a virtual environment by the manner in which the participants appropriated the existing technologies to their collaborative needs. Such characteristics include:

– *Recording Interactions versus Actions*

The WWW served the project well in acting as a repository of design material produced by the actions of the participants, such as the digital artifacts made by a variety of CAD packages. The history of these actions was recorded on the webpages. The actual intellectual power of collaborative design communities, however, resides in the interactions between participants rather than in the display of individual actions. The recording of the history of video conversations, shared workspace sessions, and streams of graphic annotations to convey threads of communal thought processes from distributed participants were not supported systematically.

The need for such support was accentuated by a simple "comment tool" used by the students. One team strongly encouraged the use of this tool, which recorded all the written correspondence between the team members and the design critics onto the team webpage.

The tool provided a systematic way of recording streams of thought by allowing continuous additions of comments to existing comments forming a coherent thread of conversation. A numbering system helped to locate the incoming commentary as insertions to the ongoing dialogue. It was successful as a mechanism for providing discrete and inter-relational evaluations of the current design concepts by the participants as well as creating a storyline for outsiders to follow. The participants preferred this representation of correspondence over email.

Although the comment tool worked well with textual commentary, sometimes supplemented with graphic explanations by the insertion of images, there was still a need for quick and easy graphic and written annotations to existing design material.

– *Responsive Design Correspondence Management*

Despite the usefulness of the comment tool, the congestion on the Internet and the speed of accessing highly graphic webpages forced the students to use other technologies in unexpected ways. One such way was the students' use of email as a forced synchronous technology during the hours prior to a formal presentation. Team members knew through familiarization and accepted notions of social practice that all members of the teams would be working at their computer stations prior to the review. They passed quick inquiries and progress reports to their partners via email instead of utilizing other synchronous video or talk facilities because it was fast and reliable when coupled with the social norm of immediate responsiveness.

Outside of these peak work hours, participants complained of not knowing if messages were received, read, and/or understood. This frustration showed some need of responsive design correspondence management where participants could communicate acknowledgements of design information exchange in a systematic manner.

– *Degrees of Reliable Interactive Communication*
Similar to the unexpected use of email as near synchronous communication of non-complex information during certain types of design sessions, the students also appropriated video conferencing to their specific needs at different stages of the design process.

The students had unlimited access to CUSeeMe for their informal discussions. At the beginning of the project, the degree of interactivity desired was high. The students wanted to see and speak to each other in addition to sharing a single digital workspace; that is, they required the international meeting to emulate a face-to-face session where facial expressions, gestural language, and eye contact form the basis for a shared understanding of a situation. Because there was a low degree of social familiarity among the participants and a high degree of complexity of design information as they dealt with conceptual design ideas, there was a need for highly interactive technologies at the beginning of the project.

Near the end of the project, however, the students rarely used CUSeeMe for validation by viewing their partners' facial expressions. Curiously, they used CUSeeMe for obtaining some shared space, such as the "talk" window which allowed synchronous communications through text and the camera for sharing spontaneous drawings. The reliability and the quality control of the text window seemed to be more manageable than the quality of verbal communications for the students who had to grapple with a language barrier as well as a bandwidth limitation. This reduced need for total interactivity, which further dropped to simple email correspondence, may be attributed to an increased social familiarity, in terms of both the team dynamics and the project itself, and a change in the type of design activity from a collaborative concept formation phase, dealing with subtle and complex design issues, to an act of refinement of design parts where there existed already a shared design conception.

2.2 Emerging practices from collaborative technologies

Using telecollaboration technologies in our everyday activities inevitably transforms, sometimes unknowingly and unwillingly, the manner in which we think about and do our work. The appropriation of such technologies and the social practices that emerge from their use create simultaneously the collaborative design environment. The understanding of this relationship of the technologies and the associated social practices may be a way to better comprehend the design process and to develop tools to support and mediate activities in this new process. Some initial observations of the practices and behaviours of the designers of the KKM studio are briefly described below.

– *Shared understanding and rituals*

Cuff (1991) described "prevailing practices and rituals" in her ethnographic study of architectural offices, where patterns of behaviour were observed through recurrent situations. She considered these patterns of activities to be loaded with symbolic meanings that expressed the value-laden culture of the office. We can begin to see such shared understanding of practices or rituals developing in the KKM project. As the degree of familiarity increased with experience and duration of the project, the teams developed their own individual methods and ethics of collaborative work.

One instance of a shared practice was a team's pattern of navigation through the group's webpages at the start of each day. Team A's members started their work session by first checking the comment page for new developments. The shared understanding of this daily ritual, however slight, by all the team members made the comment page to be a powerful communal "place" for communication. Other rituals which involved more subtle aspects of formal and informal power struggles and design roles were more difficult to concretely decipher, but the fact that the participants were vocal about their expectations of their partners' performance may indicate that these rituals did indeed exist.

– *Community Building*

In our intention to encourage the use of the computer for design work and to build a solid distributed design community with telecommunication technologies, we unexpectedly lost, as a side-effect, much of the camaraderie and expertise sharing among designers working in a common physical studio environment. The designers at MIT were not designated a common physical studio space. They, therefore, opted to work at their preferred individual locations, dispersed across campus. The use and emphasis placed on telecollaboration tools surprisingly dismissed, in the minds of the MIT designers, any need to nurture a place-based studio spirit despite its ingrained importance in architectural school culture. Because all of the design material was stored in the closed box of the computer, yet considered to be globally accessible via the Internet, the students did not lament the loss of physical pin-up and work space. We believe that the inclusion of such a communal physical space would have changed and ameliorated the nature of the collaborative experience of the KKM project at MIT.

– *Methods of Collaborative Design Understanding*

One of the major barriers of the project, as expressed by all the designers, was one of natural language. Because the meetings were conducted in English, subtleties of verbal language, which can be very important in communicating design knowledge, were difficult to send and receive between the two sites. The telecollaboration technologies also restricted the channels of communication of subtle cues in human interactivity which usually help to lessen verbal language barriers. To overcome this barrier, all the teams adopted the use of "monumental words" or keywords that were understood by all participants. This method served as a starting point for design collaboration. Through these keywords, which may be considered one mode of abstraction of more complex ideas, the teams constructed interpretations and concepts through a graphic language (Fig. 5); a language to which all designers were accustomed.

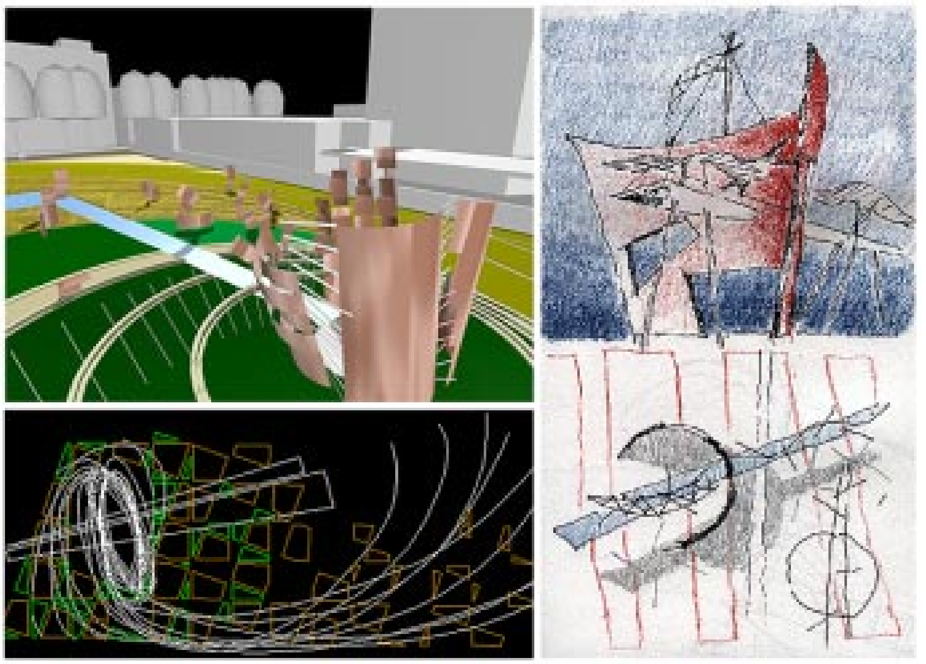


Fig. 5. Team members' dynamic interpretations of the keyword "whirlwind".

3 Learning from the KKM Project

The preliminary observations of the KKM studio provided us with some insights for our next iteration of virtual studio experiences and for future research directions in collaborative design environments. We have divided these insights in three interconnected realms: mediated design communications, technical aspects of collaborative tools, and organizational and social practices of design teams and communities.

3.1 Design communications

The restricted channels of communication of the virtual design studio have made apparent the need for establishing a language of communication that is specifically intended for conveying design knowledge. The students in the KKM studio developed a language of design communication through their use of keywords to initiate a process of design collaboration by acknowledging a shared understanding of a limited set of carefully chosen words. We may consider this abstraction of verbal language into keywords to be extrapolated to abstractions of graphic design information for developing a shared understanding for collaborative elaboration. Furthermore, we may consider the formalization of a language of collaborative communication through designer or computational design agents that perform:

– translations of keywords into graphic material
– translations of graphic material into keywords
– abstractions, transformations, and elaboration of graphic design material according to keywords or concepts.

Also embedded in the collaboration process are conventions of interactions, or rituals, that are specific to a team. These may be formalized by the team members themselves to begin to establish a particular design culture as they interact in the digital environment.

3.2 Technical aspects of collaborative tools

The KKM studio helped to determine some technical aspects of collaborative tools that could be incorporated in new technologies to ease communication and coordination in digital design environments. These include technologies that encourage and provide:

– rapid, reliable, and responsive interactive communications of complex design information
– dynamically adjustable bandwidth management for supporting varying degrees of interactivity
– recording of synchronous and asynchronous interactions in meaningful formats
– spontaneous and easy annotations of design materials in shared graphical workspaces.

3.3 Organizational and social practice of design teams and communities

The addition of geographically dispersed nodes of participants has important implications on design teams and design communities in architectural education and practice. The use of telecommunication technologies to support and mediate collaborative design work requires the re-examination of the roles and activities of designers. It is this study of the organizational and social process of design that can help us to create a non-place-based design community that complements a newly understood place-based one.

We attempted to implement a structure to build specific design communities as illustrated in Fig. 6 which included a project-centred community, consisting of the project teams; a place-centred community, involving the participants at their respective physical locations; and a task-centred community, revolving around the functional activities of the advisors, the webmasters (WM), the meeting minutes-takers (MT), and the schedule coordinators (SC).

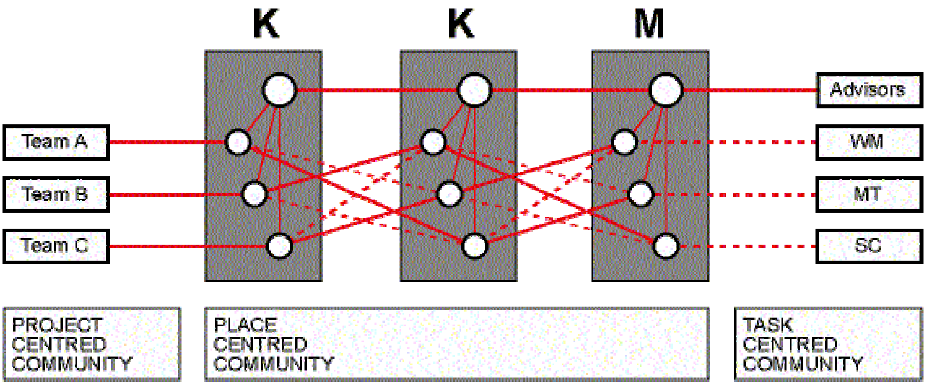


Fig. 6. Organized communities in the virtual design studio.

The project-centred community showed the strongest coherence, as can be demonstrated by the high level of design work produced. The other communities, especially the place-centred one, need further intervention in our future research. Establishing methods of interweaving both the physical and the virtual studios, with their accompanying social practices, to form a new culture of design would be an interesting and challenging task for our next iterations of experiences in the Design Studio of the Future.

4 Summary

"The most overarching observation is that the production of places is a social process. That is, a very basic task of architectural work is to collect all participants, both in the office and out, to develop a manner of working with them and to interact with them in order to create a design solution. This task, the social process, is significant to the form-giving task of architecture, for it is from this human constellation that the building's final form emerges. This simple but radical proposition is that design itself is a social process" (Cuff, 1991). It was in the spirit of Cuff's broadening of the process of architecture to include the social and cultural conditions of the act of design that we considered the Kumamoto-Kyoto-MIT case study in this paper. Although the professional practice of architecture is rarely an individual act, the idea of collaborative design communities is rarely explored in design education. Emerging telecollaboration technologies which bring together geographically distributed multidisciplinary design teams have helped us to approach Cuff's insistence of a "social art of design" (Cuff, 1991). The experiences of this project and other experiences of the Design Studio of the Future initiative are aimed at constructing a better understanding of the complexities found in the social process of design that she describes. This process is emphasized by the current and future design contexts which include computational tools to facilitate the sharing, presenting, utilizing, and interpreting of design ideas and intelligence across disciplines and distance.

The KKM studio demonstrated the possibilities created by telecommunication technologies, coupled with thoughtful social and design practices, in helping designers to transgress boundaries of time, place, and culture to form a basis for sharing expertise, interactively building knowledge, and establishing a design community.

As in any design process, the lessons learned from the experience of the virtual project will provide valuable insights for its refinement in the next iteration of experimental design studios. It is through this continual investigation that we hope to advance the development of integrated physical and virtual environments which facilitate the collaborative aggregation and communication of expertise in design fields involving clients, researchers, professionals, students, and practitioners of related disciplines and from across boundaries of time, space, and culture.

Acknowledgements

Many thanks are directed to all the members of the KKM virtual design studio at the Morozomi & Iki Lab at Kumamoto University, the Yamaguchi Lab at the Kyoto Institute of Technology, the School of Architecture and Planning at MIT for their hard work, the industry partners and sponsors of The Design Studio of the Future initiative at MIT for their vision and support, and especially to Koji Yoshii at the Yoshii Design Factory for making the design of the ArtStation a physical reality. Special acknowledgements must go to the design students of the KKM studio for their enduring enthusiasm and experimental nature: Katsuhiro Iino, Masashi Matsumoto, Masayuki Takahashi from Kumamoto University; Yasunobu Onishi, Ryoji Satsuma, Gaku Sasada from the Kyoto Institute of Technology; and Michael Fox, Scott Schiamberg, Partho Dutta from MIT.

References

1. Cuff, D.: (1991). Architecture: The Story of Practice. Cambridge, MA.: MIT Press.
2. Maher, M. L., Simoff, S., & Cicognani, A. (1996). The Potential and Current Limitations in a Virtual Design Studio. Interactive Construction Online. http://www.arch.su.edu.au/~mary/VDSjournal/index.html
3. Maher, M. L., & Saad, M. (1995). The experience of virtual design studios at The University of Sydney. ANNZAScA Conference, University of Canberra. http://www.arch.su.edu.au/kcdc/design_studio/papers/anzasca95.html
4. Shelden, D., Bharwani, S., Mitchell, W.J., & Williams, J. (1995). Requirements for Virtual Design Review. Architecture Research Quarterly, EMAP Construct, Cambridge, UK, 1, No.2.
5. Wojtowicz, J. (Ed.) (1995). Virtual Design Studio. Hong Kong: Hong Kong University Press.
6. Wojtowicz, J., Davidson, J., & Nagakura, T. (1995). Digital Pinup Board - The Story of the Virtual Village Project. In: J. Wojtowicz (Ed.), Virtual Design Studio. Hong Kong: Hong Kong University Press. 9-23

Adaptive Rooms, Virtual Collaboration and Cognitive Workflow

David Kirsh

Department of Cognitive Science
University of California, San Diego
La Jolla, CA 92093-0515, USA
Email: kirsh@ucsd.edu

Abstract. This paper introduces the concept of Adaptive Rooms, which are virtual environments able to dynamically adapt to users' needs, including 'physical' and cognitive workflow requirements, number of users, differing cognitive abilities and skills. Adaptive rooms are collections of virtual objects, many of them self-transforming objects, housed in an architecturally active room with information spaces and tools. An ontology of objects used in adaptive rooms is presented. Virtual entities are classified as passive, reactive, active, and information entities, and their sub-categories. Only active objects can be self-transforming. Adaptive Rooms are meant to combine the insights of ubiquitous computing -- that computerization should be everywhere, transparently incorporated -- with the insights of augmented reality -- that everyday objects can be digitally enhanced to carry more information about their use. To display the special potential of adaptive rooms, concrete examples are given to show how the demands of cognitive workflow can be reduced.

Keywords. cooperative buildings, collaboration, cognitive workflow, cognitive ethnography, ontology, virtual collaboration, virtual environments, virtual objects

1 Introduction

The goal in designing virtual collaborative environments is to allow individuals to do everything they can do in real shared spaces and more. As in real spaces people must be able to talk to one another, move around, make diagrams, build models, highlight points of interest for others to consider, and jointly edit documents or 3-D models. The ultimate promise of virtual reality, though, is that users will be able to do things they cannot do in real life: they will be able to conduct new kinds of scientific, business and social explorations via meetings held in "outer space," within a "molecule," inside the "combustion chamber" of an automobile engine, suspended in the "atmosphere" above planet Earth, or in Ms. Frizzle's Magic School Bus. In such cases, users will be able to jointly interact with simulations. One particular aspect of this interaction we are exploring and will report here is how to design virtual environments to dynamically adapt to the workflow needs of participants – both `physical' workflow and cognitive workflow. How should we embed simulations, information spaces, and other computational tools into virtual environments to facilitate collaborative activities?

Workflow adaptation is a thorny problem. At the most familiar level, collaborative workflow is understood in a pragmatic or `physical' manner as the activities and sub-activities – the tasks and sub-tasks -- which collaborating partners perform. Any typical job, such as assembling an electric motor, can be decomposed into a lattice of component activities. Parts must be collected, compared and sorted, then aligned correctly and fastened. Because some of these activities must be performed before others there is a partial temporal ordering on the task decomposition, hence the use of a decomposition lattice. In ordinary physical environments, collaboration makes this lattice more complicated because we must also decide who will do what; but the temporal structure of the job remains essentially the same. In this context, it is clear what an adaptive room should do: It should adapt the space, furniture and resources available, to the special needs of each sub task. If the task of comparing the parts requires lighting that is brighter than normal, then when that subtask is being performed the lighting should automatically be brighter. If the task of sorting parts requires special bins in which to group parts, then for the sorting phase new bins should appear as needed. Similarly, if alignment is facilitated by a jig, then a jig should be present to hold or re-orient the main motor. The list of useful adaptations can be extended. If several people wish to help in the assembly, and they have not decided to work separately in assembly line fashion, then the physical space around the main assembly platform should expand to comfortably accommodate more people.

This last adaptation – morphing of walls and furniture -- is one we expect to arise in most collaborative tasks in adaptive rooms. Unlike ordinary physical environments where limited space and chairs around a table or computer screen invariably means that some people must stand, in virtual rooms, any number of avatars can be seated because we can expand or deform the table to accommodate convenient placement of chairs. The computer screen, the whiteboard and bookshelves, the corkboard and the stick'ems, can all adapt. Any facet of the environment that is not currently useful may be temporarily removed. Any facet of the environment that might be useful may be temporarily added. To take another example, if I have been using my office to write an essay on adaptive rooms, and my collaborators on a different topic arrive, it is likely that my messy desk will be an inconvenience to us all. Since I wish to keep the state contained in the arrangement of papers on the table, but I also wish to have the workplace optimally configured for my current collaborative activity, I will either create a new room for this new collaboration, or adapt my office. Because the proliferation of virtual rooms for each collaboration and each activity would soon become disorienting and awkward, a better solution to this problem is to have my books and papers contract to a 3D icon, my bookshelves recede, and the whiteboard expand, all to return automatically when my visitors leave. If social needs require it, extra chairs may be whisked into the room, and any writing pads, markers and related office supplies can be provided as needed.

Adaptation to workflow conceived of as physical task decomposition is a problem designers deal with daily. It may seem, therefore, that although going virtual adds options to the design space, it adds nothing, in principle, to the design problem itself.

That is, whatever workflow requirements there are in physical space, the same requirements still apply in virtual space, though we now have new ways of meeting them. Surprisingly, this is not correct. Virtual environments allow us to create novel task decompositions. For instance, returning to our assembly task, a challenging assembly problem can be tackled by many people simultaneously in ways that are simply impossible in physical environments. Consider the possibility of four people each working with clones of the same parts, all trying to find their own solution.[1] In the physical world, instantaneous cloning is not possible; an object can be in only one place at a time; and any clones that are created soon develop their own histories and separate identities. Changes in one clone cannot be instantly propagated to all the others. The result is that many of the task decompositions we face in the everyday world are the product of physical invariants. Eliminate these physical limitations and the task lattice may be altered.

The same possibility of changing the underlying constraints of a task applies to the cognitive dimension, the cognitive workflow of a task. Cognitive workflow may be conceived of as the changing pattern of cognitive demands placed on an agent as it performs the various component activities of a task. It reflects a task's cognitive decomposition. In the subtasks of assembly for example, there are going to be more or less demanding phases for memory, perception, planning, and so forth. What makes identifying the cognitive workflow of an activity particularly difficult to anticipate, is that agents develop cognitive and interactive strategies that alter the cognitive landscape of a task. Cognitive strategies evolve in partial reaction to the resources that are available. If there is a writing pad nearby, and people have memory tasks, sooner or later they are going to discover the utility of writing down what they have to memorize. Memory can be offloaded. Similarly, people can learn to put their eyeglasses in a standard place, saving them from having to remember where they last laid them down. There are countless techniques of this sort, countless ways people discover of reconfiguring the cognitive costs of a task. Returning to assembly workers, if they have visualization tools which let them simultaneously view an emerging assemblage from different perspectives, the cognitive effort of mental rotation, normally required to determine if a candidate piece would be well placed, can be reduced. Similarly, if workers can peak over their shoulders to see what their colleagues are doing, they need not remember some of their earlier decision rationales. They can simply switch to another's assemblage if it seems more promising, or review how things would have worked out had they themselves pursued a different line of attack earlier. Perhaps they then will `jump' back to an earlier state, quickly undoing their previous decisions. Or perhaps they can be given the equivalent of layers in which to work, thereby making it possible to undo some decisions but leaving others. To be sure, as we create new assembly environments and tools, there will be complex problems of coordination both at an individual and a group level, when several lines of attack prove fruitless and collaborators must decide whose assemblage to pursue and how far to backtrack. These will raise new cognitive demands of their own. But such problems are virtuous, since they offer the possibility of all parties benefiting from parallel search. We cannot predict in advance how much this will reduce the overall complexity of the task, or what the complexity-performance trade-

[1] I am grateful to Dave Nadeau for valuable conversations about the cloning problem in VE's.

off will look like. The point stands, however, that in a virtual environment the notion of workflow, both cognitive and `physical’ workflow, is not as constrained as in true physical environments. The challenge of designing adaptive rooms, accordingly, promises to be an ongoing one, raising issues never before anticipated.

Given the exciting possibility of altering the structure of a task by altering the `physical’ constraints of the environment in which it is performed, adaptive rooms raise the provocative hope that they may take ubiquitous computing – a chief motive for creating adaptive rooms --one step beyond its currently envisioned form. The original idea of ubiquitous computing, (Weiser 1993), is that a single computer should not be the locus of computation in one's home and business environment. Technology should be embedded and distributed in the physical environment in an invisible and transparent manner. In a rich `UbiComp' environment there would be hundreds of computationally driven gadgets or smart appliances throughout, each one part of a larger system of coordinated devices. These objects transmit and receive signals from neighboring objects and often act on them in a context sensitive manner. Many of the objects communicate tacitly, using ambient sensing, such as sonar or video to pick up change. Although these objects do not transmit coded signals to each other they still interact in helpful and often apparently intelligent ways. In particular they are not intrusive. A classic example is a sensor which recognizes my entrance and adjusts the room temperature, lighting, and music, to my preferred levels. As I move about, sensors of this sort will interact with the phone system and help decide which phone to ring and whether to use a distinctive ring for me. If I close my door after a colleague arrives, my room will `know' I wish privacy and route my telephone calls to voice mail. When I sit down at a computer monitor the blinds will draw appropriately to prevent glare. Some of this coordination is achieved through explicit signaling between devices, other aspects of the coordination is achieved tacitly by detecting my movement through ambient sensing.

Our goal in adaptive room research is to unite the power and flexibility of virtual environments with the insight of ubiquitous computing. In effect, it is to simulate the behavior of systems of future smart objects, and to enhance the possibilities of ubi-comp rooms by using digitally enhanced objects. To properly design adaptive rooms along these lines we must be sensitive to three requirements.

1. The various cognitive and physical workflows occurring within it;
2. We need to tune rooms to the social needs of users as they interact.
3. We need to maintain environmental coherence across room changes. Adaptive rooms are supposed to be comfortable habitats, not Alice in Wonderland nightmares.

The remainder of this paper has two parts. In the first and largest part, I discuss the ontology of objects necessary for understanding and designing adaptive rooms. In the second, I offer a few illustrations of how cognitive workflow can be changed by the clever use of environmental resources, and a brief example of how these workflow ideas figure in a collaborative task. I then draw a few implications for the design of adaptive rooms.

2 An Ontology for Adaptive Rooms

The highest principle of HCI design holds that it is the environment which should be adapted to users rather than users who should have to adapt to the environment. Characteristically, this has meant organizing the layout and tools available in a software application in a convenient and customizable way to make it easy for users to rearrange their working environments the way they like. When this principle is extended to more dynamic virtual environments, where environments may automatically adapt to users' activities in more sophisticated ways than simply activating and deactivated tool sets or changing the position of icons, a host of new problems arises that are associated with naturalness of change, plausible adaptation to context change and environmental coherence. If the result of changing a room to accommodate a change in the social context, such as shifting from a discussion to a Powerpoint presentation, is to change the design so radically that the new room bears little resemblance to its previous self then it hardly makes sense to call the newly designed room the same room as the original. It will have been stretched beyond recognition and the cognitive benefits to the user of knowing where he or she is spatially will be destroyed by the confusion that arises from cognitive disorientation.

To properly understand such problems requires empirical study of people's reaction to room adaptation - an empirical study we are just beginning. To be sure, there is empirical precedent for room redesign in the reconfigurable walls which Le Corbusier promoted in the 1930's and 40's, (Le Corbusier, 58), and the open plan education movement in the United States of the 1950's, (Bay, 79), which further developed some of these ideas. But the physical rearrangement of walls and furniture to meet the educational and activity needs of groups was not an architectural transformation which happened automatically and transparently. There were no invisible agents and smart objects acting behind the scenes making adaptations in response to the physical task and social cues in the environment. Rather an open plan room was reconfigured only after a sustained process of discussion and negotiation among the participants. Human deliberation was involved. Consequently, the empirical studies of open plan teaching do not carry immediate implications for Adaptive Rooms. Indeed, since the very teachers and students who were using open plan spaces were the ones who physically reconfigured the space, the sorts of concerns about coherence typical of automated adaptation did not arise in open plan classrooms because members had time to adapt themselves to the new layout.

To set the framework for a principled study of Adaptive Rooms it will be useful to begin our inquiry with the ontology of entities that inhabit and constitute them. At a concrete level these include walls, whiteboards, furniture, agents, and other potentially smart or self-adapting entities. But the goal here is an abstract ontology. As a first cut let us distinguish four types of virtual objects: passive, reactive, active and information spaces. Each of these poses a different type of problem for programmers.

2.1 Passive objects

A virtual object is passive if it can change absolute state (shape, color etc.) or relative state (position, orientation) when a human agent or some other active object interacts with it, but is otherwise unaffected by changes in the absolute or relative state of other objects. For instance, we assume that in a simple virtual environment, one which lacks illumination and shading, a simple object, such as a table, will be unaffected by the activity of neighboring objects. Drop a heavy vase on it and the table does not dent. Push a chair against it and it does not move. Humans may rearrange the location of chairs, or possibly alter their color or texture. But such changes do not occur in automatic response to other changes. The primary architectural elements in simple environments -- walls, ceilings, and floors -- are passive in this way. So is fog, and so, of course, have been the early versions of virtual objects.

2.2 Reactive objects

A virtual object is reactive if it can change absolute or relative state, not only as a result of actions on it by agents but in response to changes in other objects. For instance, objects which break when struck by another object are reactive objects because they change their shape and number – their absolute state – and change their position and velocity – relative state – in response to the change in position and momentum of the object colliding with them. We may summarize the difference between reactive and passive objects by saying that reactive objects obey `physical' laws of interaction. Such laws specify how objects cast shadows over surfaces (hence how they become shaded by the other objects); how the absolute state of objects change according to the force, and shape of objects impacting them; how objects change their relative state (position, velocity, acceleration, orientation) as the result of forces. Some of these laws, such as the laws governing reflectance and shading, are global laws of physical interaction and apply throughout a virtual environment. Other laws are highly specific, potentially complex physical constraints, and apply only to particular objects in particular conditions. For instance, the way a couch deforms when a person sits on it depends on the person's weight, speed of sitting, as well as the relative position of other cushions. General physical principles are at play here, so these constraints do not lie outside the physics of the virtual world, but the initial and boundary conditions of pillows on a couch are so unique that it is best to think of the couch as having its own specific laws of interaction -- the physics of couches. As the number of objects increases, it becomes extremely hard to specify a realistic set of interactive physical laws, though luckily, for many interactions, a feeling of realism may be achieved by rough approximation to these laws.

The items of furniture found in Adaptive Rooms may behave as reactive objects, or they may be more active – closer to what we would call smart furniture – and so capable of self-transforming in ways that go beyond reaction to simple physical events. It is the designer’s choice. He or she may choose to program virtual chairs to behave much like their physical counterparts – as reactive objects in my terms -- or they may be programmed to be smart. If they are standard reactive chairs then they will deform when sat on and move when struck, but otherwise will be inert to changes in their immediate vicinity. In particular, they will be unresponsive to social events such as the number of people trying to sit in them. If they are programmed to be smart – to be active objects -- then they might morph into a couch, or multiply themselves.

2.3 Active objects

Furniture that can self transform, such as tables that can change dimension, lights that automatically move to accommodate extra participants, or bookshelves that shrink or expand, are more complex than reactive objects in two ways. First, they are able to react to changes in social conditions -- the number of people present, the social function of the meeting (e.g. presentation, intimate chat, virtual office meeting, disciplinary discussion, and so on). Second, their reaction goes beyond physical law. They are able to self transform, changing their size, position, appearance, shape and even functionality as appropriate. For instance, if several people enter my office, the books on my bookshelf may transmute into a single icon representing the entire set, the shape of my lamp may alter so that it now projects two distinct beams rather than the one it was projecting before, and my overhead projector, which normally is under the control of whomever is beside it, may change its functionality to now allow non presenters (e.g. participants sitting at the other end of table) to annotate projected slides in whiteboard fashion, provided they are sitting in seats known by the projector to be reserved for participants.

Let us call a virtual object an active object if it is both responsive to interactions with other objects and is able to take actions either on its own or in response to abstract changes in its milieu. Furniture which morphs to meet social needs fits this definition, so do autonomous agents since they are able to autonomously change their position, and orientation, possibly even their internal state, without explicit direction from human agents; and so do human avatars, of course, since they may act unprompted by any apparent changes inside the environment.

Each of these active objects has its own distinctive properties. Autonomous agents, for instance, typically have standing instructions to maintain certain properties of the environment, such as keeping a space tidy, or re-aligning chairs when they are disturbed. They may also have more complex standing instructions to respond to specific requests such as helping humans (or other agents) to locate textual references. (If their role is information related they may be better classified as information objects. But understandably their category membership is ambiguous.) Agents which seem to be reacting to changes in environmental state – e.g. untidiness, or disorder – are not classified as reactive objects because the state they are responding to is abstract, and not governed by laws of physical interaction. For example, an intelligent agent for inventory control that is responsible for restocking its collection of office supplies as soon as its inventory falls below a certain threshold, is responding to a change in the environment, but there are no physical laws about maintaining inventory. Active objects typically have their own agenda and follow their own individual laws programmed into them. Agents which follow or are responsive to social norms also qualify as active objects. Programming such agents is a challenge because the interpretation of social events is a complex matter and typically relies on being able to attribute motives and beliefs to social participants. Simplified versions of socially aware agents, however, might be able to do such things as move out of the way of an aggressive agent, help another avatar or agent to balance a teacup about to fall, or even stagger back in `horror' when menaced. As virtual environment's become more complex it becomes increasingly important to make agents sensitive to social conditions, though if programmers are not to be behavioral reductionists this will continue to be a formidable task.

For clarity, we shall further distinguish agents which have a regular *physical presence* in a virtual environment from those that are *invisible*, and which are either configured in advance of entering the environment or which can be called up from an environment with their own user interface. Agents which perform tidying tasks such as furniture straightening, or agents configured to maintain the look and feel of a certain room, , are examples of invisible agents which need be called up only when there is a need to modify their agenda. Butler-like helping agents which perform various office duties and which keep a regular physical presence are examples of visible agents.

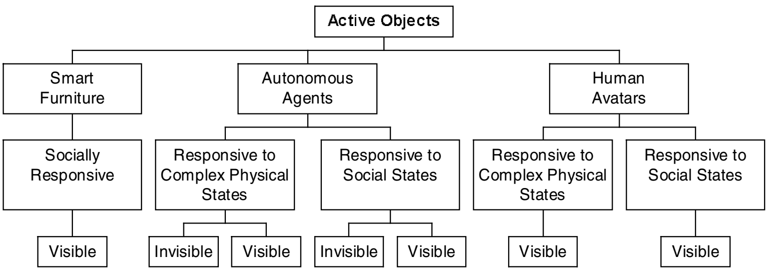


Fig. 1. Here is a simple hierarchy of active objects found in virtual environments. What differentiates most active objects from reactive objects is that they are sensitive to social 'laws' or to highly specific changes in other objects. They therefore are capable of self-transformng actions where they morph, iconify themselves, or perform helpful duties.

2.4 Information objects

In addition to active objects there are also two types of active information entities: *information tools* and *information spaces*. Both have a clear functional purpose: to help users to find information they feel would be relevant to their current activity. An information tool is a visualizing tool that allows its user to explore the contents of a document in a special way. It might be as simple as a tool showing all the paragraphs that contain a given phrase or word, or it may display certain statistical properties of the document. It is a device for visualizing contents. We may imagine it as akin to a lens that can be run across an open document or an unopened book.

An information space allows users to display meta-information about books, articles, magazines, web sites, and to list this meta-information and sort it. In Adaptive Rooms the empty space in a bookshelf, or a corkboard, would likely serve this function. In its most obvious form, the bookshelf space behaves like the display field of a file system, with tabs that can sort entries by date, size, type, title, and so on. Users can invoke a search of the web, digital libraries and so on, or perhaps autonomous agents will be programmed to retrieve sought after material and post pointers in an appointed information space. The information displayed is active. Just as html documents contain url's to other documents, so the display of meta-data in information spaces are hypertext pointers that, when clicked on, result in the relevant book, article etc. arriving in a physical form and lining up on the shelf. Once the books have arrived on the shelf they can be sorted according to several categories: date, author, title, keyword etc. So the entire bookshelf containing books, articles, and other documents, as well as the open space at the end of the books grouped together serves as an information space where information relevant operations can be performed.

2.5 Does cloning and linking complicate an ontology?

It was mentioned earlier that the physical workflow of an assembly task undertaken in a virtual environment may be different than its physical correlate because it is possible to clone parts and assemblies in virtual worlds, and so distribute problem solving among collaborators in ways that have no counterpart in the physical world. This means that objects in a virtual environment are no longer individuals, but rather types that can be tokened at will. At first this may seem to be no stranger than multiple versions of a document. In collaborative writing, for instance, each collaborator soon develops his or her own version of a document. This has the consequence that there is either a problem of putting together the final version, or there are tight restrictions on who may write to the canonical version. But in assembly tasks, there need be no intermediate canonical versions that must be shared since there may be multiple solution paths. This means that there can be a wild proliferation of partial clones during assembly and no need for version control. But then how are we to characterize such clonable objects? Do they force us to revise our ontology?

The matter becomes even more confusing ontologically, when we consider other tasks, such as jigsaw puzzling. In solving a jigsaw puzzle collaboratively, we may allow players to individually search for placements on their own version of the game, but to enjoy immediate updates of their boards when any of their collaborators find good placements. In simple jigsaw puzzles, it is possible to hill climb to the goal without concern that there may be false or misleading placements. This has the implication that there is no need to assign version numbers to partial puzzle solutions at all: any advance can be shared by everyone. Accordingly, multiple copies of the game can be causally linked, so that a change in one game is propagated to all. But then what sort of ontological status will such multiplicities have?

Such questions raise important issues for designers of collaborative environments. Any theorist eager to explore the ontology of virtual environments must decide how to treat versions and linked multiplicities. For the moment, however, we may note that multiple instantiation, or cloning applies to all virtual objects, regardless of category. Passive and reactive objects may be cloned as well as active objects. Whether human avatars may be cloned is a design choice.

2.6 Interim summary

Assuming that our ontology represents a useful starting point we can say that Adaptive Rooms are collections of virtual objects, mostly self-transforming objects, housed in an architecturally active room with information spaces. The entities of Adaptive Rooms are sensitive to interactive laws of both a physical and a social sort, so many of them respond in a coordinated way as if under the control of a thoughtful butler, always looking for ways to make one's task easier. It is in that sense that self-transforming objects are the virtual counterpart to smart objects and smart appliances discussed in the literature on Ubiquitous computing. Our objective is to design the objects in our virtual world with enough intelligence and coordination to act politely, to anticipate users' wishes, and to change their behavior with the context of action. Since there is always a danger that too much cleverness may get in the way of effective collaboration, we can only determine the cleverness threshold of smart objects and tools by considering the way they fit into the work flow of collaborators and the resources they use. In short, the way to design a new collaborative environment is to first understand the way human agents and their everyday objects, representations and gadgets constitute a system of distributed cognition. It is to that we now turn.

3 Work Flow Analyses and Distributed Cognition

To construct useful Adaptive Rooms requires a deep understanding of:

1. How people use resources individually and jointly as they go about their tasks in everyday environments. This is the pattern of work that should be facilitated in an Adaptive Room.
2. How users will adapt the way they do their tasks once they have adaptive virtual rooms to help them. Put differently, we must understand the way external users will interact with Adaptive Rooms as part of their larger ongoing activities.

A few quick examples of the way people use resources around them in everyday environments will help to illustrate why the type of understanding required by point 1. is particularly challenging.

In observing agents interacting with their environments, we have noted that they are constantly managing the resources around them. (Kirsh 96). Much of this activity is quite naturally pragmatic: it is directed at getting things done and accomplishing goals. For instance, people choose, reach for and pick up books and notepads in order to draft memos and outlines. They build models to help solve problems, and they move objects such as chairs around to make it easier to perform their tasks. The rational structure of pragmatic activity is familiar enough: first complete the sub-goals of a task and then combine these sub-goal states to complete the overarching task. It is reasonable to hope that someday many of the component parts of our pragmatic activities will be automatically carried out by agents in a virtual environment. The idea of smart butlers fits that model. The user initiates an action, perhaps by request, perhaps by gesture, and the butler infers some of the necessary sub-goals and so completes the drudge work part of the activity. Our research has shown that a surprising amount of action, however, is not really pragmatically oriented. People seem to spend much of their time performing actions that serve cognitive or epistemic functions rather than pragmatic ones. [Kirsh and Maglio 95]. These actions do not fit into the standard goal sub-goal model of planning and rational action. They are more tightly coupled to the memory, reasoning, and perceptual systems of the people performing them. Hence although some non-pragmatic actions might be anticipated by a smart butler many would lose their effectiveness if executed by someone other than the cognizing agent.

Among the many non-pragmatic activities we have observed and documented include:

- Positioning objects to draw attention to opportunities (e.g., card players arrange their hands to encode plan fragments and possible opportunities).
- Arranging objects to cue action selection or constrain options (e.g., lay out parts in the order they need to be assembled).
- Configuring objects to “remind” users of plans or intentions (e.g., leave keys in shoes, film by the door).
- Preparing the workplace so that the average complexity of tasks that must be done is lower -- amortize the complexity of tasks by paying an up-front cost in preparation -- (librarians pre-sort books to be shelved on carts before moving to the stacks);
- Pointing with hand or mouse to help direct attention or increase the acuity of perception, as in counting coins, or looking for a name in the phone book. (Kirsh 95b);
- Rotating objects physically to save the need to rotate them mentally (rotating tetris pieces (Kirsh and Maglio 95), righting upside down photos (Kirsh, forthcoming));
- Clustering items to create ad hoc categories that are problem-salient (e.g., organizing articles on one's desk to highlight those that are relevant to a current project).
- Re-arranging objects, such as Scrabble tiles, to self-prime or self-cue recall.

In each case what is noteworthy is that agents make short and medium term adjustments to their environments for cognitive reasons: to keep processes manageable, and on track. The conclusion to be drawn is that the environment is one’s partner or cognitive ally in the struggle to control activity. Although most of us are unaware of it, we constantly create external scaffolding to simplify our cognitive tasks. Our goals as designers is to create digital environments which make this cognitive alliance as powerful as possible. Helpful workflow analyses must focus on how, when, and why this external scaffolding is created.

3.1 A simple scenario

One collaborative context we are working on focuses on the joint efforts of a marine ecologist, Mr. E, and a geographer, Ms. G. This is a familiar situation: two researchers, each an expert in their own field, join forces to tackle a problem that neither one can quite handle on their own. Ms. G lives on the east coast but regularly visits Mr. E in his office on the west coast. The physical room they typically collaborate in -- E's room -- has a desktop PC, a Silicon Graphics machine, as well as E's laptop. There is a whiteboard, corkboard, shelves, books, calculator, ruler, three chairs, and a host of sundry other objects, which are in constant use. Because G knows cartography and the geographical information system packages, while E specializes in more theoretical issues, G tends to take the driver's seat in front of the Silicon Graphics machine when they are involved in making a map, with E looking over her shoulder, or working on different material on his desktop PC. E also keeps a small bound notebook with useful parameters tried in the geographical information system package. Since this information helps them keep track of their inquiry, G and E must explicitly resolve their schedules to ensure that this book is where G may find it when she returns to the room and E is not there, or else the must find some other means of guaranteeing that she finds out the parameters E tried when he was on his own. Naturally there is much more to be said about the social arrangements that holds between the two and to the different resources they use individually or jointly. The whiteboard, for instance, plays an important role when E is talking but considerably less so when G is talking.

From our preliminary studies a few non-obvious facts have emerged about the mechanics of collaborative workflow. First, opportunistic encounters in the hallway, outside E's office, and near the coffee machine are important catalysts for their work together. One often thinks of collaborative meetings being scheduled or at least unproblematically occurring. But because much important work occurs during unscheduled conversations, special efforts have to be made in virtual environments to create the right opportunities for informal contact. Second, it is apparent that both E and G take the opportunity to look over the other's work when one of them is out of the room. Data maps are dense and the information represented on them requires a fair bit of study before a viewer feels fluent with them. Accordingly, collaboration is a much larger activity than simple face to face meeting. The state one leaves one's office in, or the state of one's computer screen can be extremely informative to one's partner. Coming early to a meeting can be helpful as means of preparation. But then since helpful state may be stored in notebooks, corkboards, whiteboards and ink marked books, the use of all these resources must be temporally coordinated. Users would like to `page through' the previous stages of work -- not change by change, but collection of changes at a time. Markings that go together -- either by date or content -- ought to be retrieved in a connected way, saving the user from figuring out when a mark on the blackboard was part of one conversation or another, and saving them from having to personally know where to look for relevant documentation (in cases where, for instance, a mark has been placed on whiteboard or notebook after a book has been consulted). Moreover, since these are all resources that may be `messed with' during ordinary non-collaborative activity, it is important to be able to restore or maintain the state of these books despite the other activities one might perform in the same space.

Admittedly, nothing said here is detailed enough about the tasks each participant performs to expose the cognitive or physical workflow of E and G's personal and collaborative activity. But even this cursory account may suffice to show that virtual collaboration may be better than face to face collaboration if it offers participants the capacity to intelligently recover the structure of each other's workspace.

4 Conclusion

Our designs of Adaptive Rooms are guided by three principles:

1. Wherever possible Adaptive Rooms should adapt to humans rather than humans to them;
2. Adaptive Rooms should be populated with cooperating smart objects and tools to make our virtual environments like digitally enhanced futuristic ubiquitous computing environments.
3. An adaptive room and the agents in it constitutes a system of distributed cognition. Problems are solved by coordinating resources in and outside of peoples' heads.

By following these principles we believe that the insights of ubiquitous computing -- that computerization should be everywhere, transparently incorporated -- can be merged with the insights of augmented reality -- that everyday objects can be digitally enhanced to carry more information about their use. The result is an integrated virtual environment in which people can cooperate and collaborate on projects that leverage the computational strengths of computers.

References

1. Bay, S. L. (1979). A study of conditions encountered when traditional educators work in an open space school. Experiential Education. Mankato State University.
2. Kirsh, D. (1997). Interactivity and Interfaces. Instructional Sciences, 25, 79-96.
3. Kirsh, D. (forthcoming). Are all Actions Exploratory or Performatory? Ecological Psychology
4. Kirsh, D. 1996. Adapting the Environment instead of Oneself. Adaptive Behavior, 4:3/4, 415-452.
5. Kirsh, D. (1995a). The Intelligent Use of Space. Artificial Intelligence, 73, 31-68.
6. Kirsh, D. (1995b). Complementary Strategies: Why we use our hands when we think. In: Cognitive Science Society Proceedings. Mahwah, NJ: Lawrence Erlbaum.
7. Kirsh, D., & Maglio, P. (1995). On Distinguishing Epistemic from Pragmatic Actions. Cognitive Science. 18, 513-549.
8. Le Corbusier, & de Pierrefeu, F. (1958). The home of man. Translated by Clive Entwistle and Gordon Holt, London: Architectural Press.
9. Weiser, M. (1993). Hot Topics: Ubiquitous Computing. IEEE Computer, October.
10. Weiser, M. (1993). Some computer science issues in ubiquitous computing. Communications of the ACM, 36,7: 75-84.

The Metaphor of Virtual Rooms in the Cooperative Learning Environment CLear

Hans-Rüdiger Pfister, Christian Schuckmann,
Jennifer Beck-Wilson & Martin Wessner

GMD - German National Research Center for Information Technology
IPSI - Integrated Publication and Information Systems Institute
Dolivostr. 15, D-64293 Darmstadt, Germany
Email: [pfister, schucki, wilson, wessner]@darmstadt.gmd.de

Abstract. In the CLear project we develop a cooperative learning system for supporting learning and training processes of co-located and distributed groups. One of the fundamental concepts of CLear is the virtual room metaphor. We discuss divergent interpretations of this metaphor each appropriate for certain aspects of the learning process. We are exploring the implications of using such a metaphor for supporting collaboration, structuring hypermedia information and supporting the learning process in general. Our aim is to define a virtual room metaphor that integrates the collaborative aspects as well as the need to structure learning content contained within this system.

Keywords. cooperative learning, virtual rooms, activity spaces, knowledge structuring, mental model, hypermedia information

1 Introduction

CLear is a cooperative learning system for supporting learning and training processes. It utilizes a hypermedia data model which enables flexible information structuring and cooperation capabilities. CLear is based upon the DOLPHIN system (Streitz *et al.,* 1994), and a first prototype has been built using the COAST framework (Schuckmann *et al.,* 1996). Whereas DOLPHIN focuses upon meeting support, the CLear system, currently in an early prototype stage, supports a wide variety of learning situations involving both co-located and distributed groups. CLear is part of a concerted effort at GMD-IPSI to develop flexible and adaptive means of supporting learning and working collaboration activities within and among co-located and distributed organizations.

In CLear we use the metaphor of the virtual room for visualization. Waterworth and Chignell (1989) stated: „One of the major unresolved issues in hypermedia usage is how to provide visualization tools based on spatial models of information.“ We have learned that various approaches using this metaphor have specific implications for supporting collaboration, structuring hypermedia information and supporting the learning process in general.

As shown in Fig. 1, in the virtual world of CLear each participant, or inhabitant, „owns“ a room, i.e., a personal location. The rooms provide functionalities to create, retrieve, store and modify hypermedia information. Furthermore, rooms may be shared by some (group rooms) or all participants (auditorium). Taken as a whole, the assembly of virtual rooms constitutes a virtual world consisting of several locations. Since all rooms share common functionalities to communicate, the CLear system can also be understood as a *virtual cooperative building*.

Fig. 1. A screen shot of the CLear prototype World browser showing various virtual rooms and inhabitants

At issue currently is the exact structure and composition of these virtual rooms within the CLear environment: On the one hand, the virtual room metaphor can be perceived as a type of *activity space* (Streitz *et al.,* 1989) providing various collaboration functionalities to participants. A virtual room is then defined according to its functions: a virtual auditorium provides different types of functionalities than a virtual group room or personal room, for instance. Card and Henderson (1987) have developed the Rooms metaphor in such a way. On the other hand, the virtual room metaphor may also be perceived as being related to content or *knowledge structuring*. Given such an outlook, virtual rooms are then defined by the content which they contain. A virtual library serves as a repository of structured content. Each of these virtual room definition specifications has merit and the CLear system attempts to incorporate both approaches in some fashion. A key question is how to integrate these two approaches. Below, we elaborate upon each of the two views beginning with the collaboration support aspect.

2 Using the Metaphor of Virtual Rooms to Support Collaboration

2.1 Rooms in the real world

Collaboration in the real world takes place at specific locations. People meeting at a location can see and hear each other and thereby communicate. Furthermore they can see and manipulate objects which are also at that location and thereby can collaborate. A room is a location that has borders (i.e. walls) to separate it clearly from other locations. These borders limit both whom users can see/hear and what they can see/manipulate. Rooms are therefore a means to *structure collaboration*.

People place information objects (e.g. books, notes, a whiteboard) in the rooms where they want to use these objects. Additionally, these objects are arranged in sublocations within that room (e.g. shelves, drawers, folders, etc.), enabling people to find and organize specific information. Rooms are therefore also a means to *structure information*.

Furthermore, rooms are *designed for specific types of work or collaboration*. For example, an office is designed for individual work and contains personal objects with which the inhabitant of the office currently works. Other rooms are designed for large groups, e.g. an auditorium is designed for one presenter and many participants and contains presentation material that is used by the presenter. Fig. 2 shows yet another type of work room, a *Group Room* in which two or more participants work cooperatively and are aware of one another's presence.

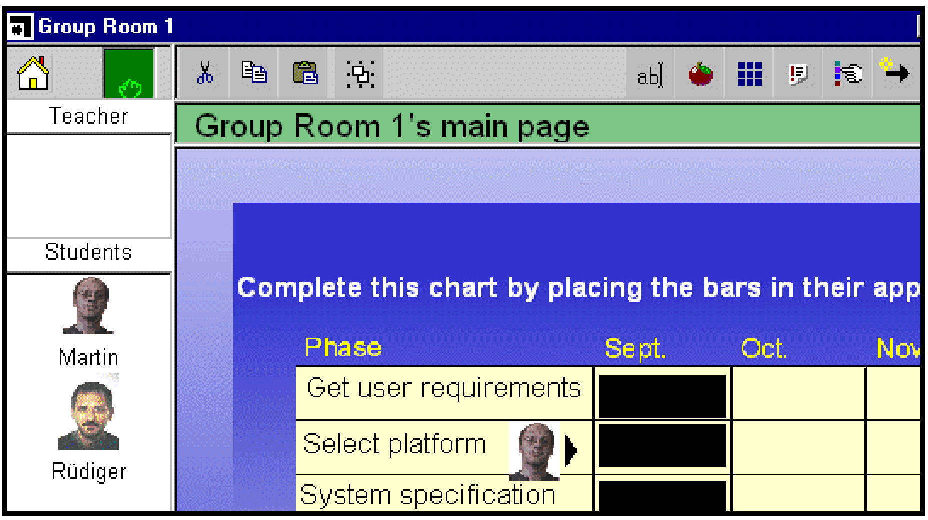


Fig. 2. A screen shot of a virtual group room featured in the CLear prototype. Here two participants are working cooperatively. At the moment, Martin is using the telepointer feature to specify an object.

Finally, rooms are used to *control access* to objects contained in the room and to control access to the group of people in the room. Rooms have doors that can be open (i.e. everybody can come in) or closed (i.e. you would need a key or would have to ask for entry permission). Furthermore closets, drawers, and other objects within the room can also be locked.

2.2 Related Work: Virtual rooms in CSCW systems

There have been several approaches to transfer the metaphor of rooms into CSCW-systems (e.g. Roseman & Greenberg, 1996; Waterworth & Singh, 1994; Card *et al.,* 1991). A main advantage of using such a metaphor is that people are very well used to it from the real world. However, virtual rooms do not have to resemble real rooms in every aspect, especially if the virtual world could offer some improvements (e.g. fast travel between rooms, infinite storage space in a room).

Collaborative virtual environments (CVEs) try to reflect the real world as much as possible. CVEs use a 3D world and visualise this world with virtual reality techniques. People can have a virtual representation in this world (so-called embodiment or avatar) and can travel through the world meeting other embodiments or interacting with objects in the world. However, CVEs focus more on supporting communication and not so much on collaboration.

Multi-user dungeons (MUDs) only partially reflect the real world. MUDs introduce virtual rooms that are connected and virtual persons can move from room to room along those connections. The connection structure often resembles the real world (e.g. you can move east, up etc.), but this is neither necessary nor strictly followed. With MUDs being described by text only (as opposed to VR techniques) it is up to the author how closely the MUD follows the limitations of the real world.

TeamRooms. This group support system (Roseman and Greenberg 1996) also introduces virtual rooms. Team rooms are not connected or put into a spatial relationship with each other. So, the analogy to the real world is rather low compared to MUDs and CVEs. However, TeamRooms focus on collaboration by providing objects that can be manipulated cooperatively. Team rooms also have doors and thereby allow some access control.

3 Using the Metaphor of Virtual Rooms to Structure Knowledge

Virtual rooms provide an easy to understand *spatial metaphor* which is particularly suited to support learning as *mental model construction* (as opposed to routine skill learning). Virtual rooms support knowledge structuring, provide a mnemonic device, and a means to communicate knowledge. Furthermore, virtual rooms and buildings provide a natural analogue to real life learning situations. Hence, learners have a background knowledge for orientation and behavior in the learning environment. As in the real world, each virtual room contains content which can be structured to facilitate learning.

According to Shavelson (quoted from Churcher, 1989), „knowledge of structure is necessary for a full understanding of a subject, it enhances retention, facilitates problem solving, leads to transfer, results in intellectual excitement and develops an aptitude for learning.“ As users navigate through the various content rooms, they begin to structure or chunk information in a meaningful way which promotes acquisition of knowledge. Finally, virtual rooms allow learning to be embedded in other activities, such as working or social communication. This flexibility makes the virtual room metaphor compatible with constructivist (Jonassen, 1991) and situated learning theories (McLellan, 1995) as well as applicable to the structure and performance of user groups.

3.1 Mental models

Many forms of learning take place as a kind of mental model construction (Genter & Stevens, 1983; Glenberg & Langston, 1992). During the encoding process, information (such as written and spoken language, or other perceptual and symbolic information) is represented and understood by forming a mental model of the learning situation. Mental models usually are:

- *situational*, i.e., they represent the learning context and the content to be learned simultaneously;
- *dynamic*, i.e., constantly reconstructed and modified during the learning phase and after the learning phase under different contexts of application;
- *analogue-spatial*, i.e., concepts and semantic relations are mentally represented by spatial relations among objects and classes of objects; and
- *perspective*, i.e., the spatial representation centers around a protagonist, usually the learning individual himself.

For example, students learning about electricity could envision a pipe flowing with water which then becomes a current creating energy.

3.2 Implications for learning

Mental models are formed as temporary constructs in working memory. The actual mental model mediates the concurrent assimilation of new information, i.e., it puts constraints on what will be encoded and on how it will be represented. In sum, mental models:

- constrain which new information is learned and how it is represented. (New semantic relations have to fit into the existing spatial structure, the limited capacity of working memory determines the amount of activated information.)
- determine which information is presently available. (Retrieval centers around the protagonist´s perspective, retrieval paths follow the spatial topology of the mental model.)

All functions are supported by a virtual room learning environment:

- *providing a representational and mnemonic device* (e.g., in the sense of the loci method) to store and recollect information, integrate information (formation of chunks), and connect information (e.g., mapping semantic onto spatial relations).
- *providing metaphors to constrain the amount and structure of learning.* Access to rooms (open/close), connection of rooms (floors etc.), association of specific knowledge with specific rooms, and chunking as the creation of new group rooms.

In addition, cooperative learning may be viewed as three simultaneous activities: content learning, learning social structures, and learning to learn cooperatively. These activities are not independent. Which content is to be learned determines which social structures are relevant. The way the learning group is organized determines what is learned by the individual participants and who has control over the learning process. Both content and group structure determine the degree of cooperation necessary for learning as well as the additional gain in cooperation capability resulting from successful learning.

The virtual room metaphor supports learning group structures/relations by

- providing a spatial analogue to group relations
- adapting to different group structures (trainer & learners, individual learner, tutor & learner)
- adapting to different task types (document editing, problem-solving, brainstorming)
- providing a simple means to restructure groups during learning (group rooms)
- constraining interaction as necessary (access rights)
- facilitating individual learning as well as group learning (own room)

4 Research Issues and Outlook

Since the CLear system works on a hypermedia database we *map the hypermedia structure to the virtual room structure.* At issue is how to map complex hypermedia structures to virtual rooms. On the other hand, the virtual room structure needs to be *matched to the cognitive representations* of the learners, i.e., to the evolving mental models during learning. As stated above, we assume that (a) the 2 or 3-dimensional spatial structure of virtual rooms is more appropriate for learning (at least for early phases) than complex hypermedia structures, and that (b) content organized by virtual rooms supports the construction of mental models. Both assumptions need further empirical testing.

In a similar vein, virtual rooms are used to *represent group structure* and inter-group relationships by assigning different rooms to different persons. We assume that cooperation and communication is facilitated by associating participants with specific locations; this especially supports the flexible reorganisation and spontaneous creation of new subgroups. A problem that might arise is that group structure and content structure do not converge onto the same virtual room structure. How to match and integrate content and cooperative relations will be another major research issue.

In sum, cooperative learning is a complex process exceeding learning content. Virtual rooms are a logical way to map group structures and provide flexible means to constrain group relations and communication as well as to map content structure. We are working on an integration of these approaches that will allow learning to be embedded in other activities, such as working or social communication, and make the room metaphor compatible with constructivist and situated learning theories. We will evaluate the CLear prototype with a small group of real users (university class) beginning in January, 1998. From this evaluation we intend to gain valuable information regarding the future direction we will take in developing the virtual room metaphor.

References

1. Card, S.K., & Henderson, A.H. Jr. (1997). A multiple, virtual-workspace interface to support user task switching. In: Proceedings of the CHI+GI, Toronto, Canada (April 5-7, 1987). NY: ACM. 53-59.
2. Card, S. K., Robertson, G. G., & Mackinlay, J. D. (1991). The information visualizer, an information workspace. In: Proceedings of ACM Conference on Human Factors in Computing Systems (CHI'91) New Orleans, LA (April 27-May 2. 1991). NY: ACM. 181-188.
3. Churcher, P. R. (1989). A Common Notation for Knowledge Representation, Cognitive Models, Learning and Hypertext. Hypermedia, 1, (3), 235-254.
4. Duffy, T. M., & Jonassen, D. H. (1991). Constructivism: New implications for instructional technology? Educational Technology, 31, 7-12.
5. Genter, D., & Stevens, A.L. (Eds.) (1983). Some observations on mental models. Hillsdale: Erlbaum.
6. Glenberg, A. M., & Langston, W. E. (1992). Comprehension of illustrated text: pictures help to build mental models. Journal of Memory and Language, 32,129-151.
7. McLellan, H. (1995). Situated Learning Perspectives. NY: Educational Technology Publications Englewood Cliffs.
8. Roseman, M., & Greenberg, S. (1996). TeamRooms: Network Places for Collaboration. In: Proceedings of the ACM 1996 Conference on Computer Supported Cooperative Work (CSCW'96), Boston, MA (November 16-20, 1996). NY: ACM. 325-333
9. Schuckmann, C., Kirchner, L., Schümmer, J., & Haake, J. M. (1996). Designing object-oriented synchronous groupware with COAST. In: Proceedings of the ACM 1996 Conference on Computer Supported Cooperative Work (CSCW '96), Boston, MA (November 16-20, 1996). NY: ACM. 30-38.
10. Streitz, N. A., Geißler, J., Haake, J. M., & Hol, J. (1994). DOLPHIN: Integrated Meeting Support across LiveBoards, Local and Remote Desktop Environments. In: Proceedings of the ACM 1994 Conference on Computer Supported Cooperative Work (CSCW '94), Chapel Hill, NC (October 22-26, 1994). NA: ACM. 345-358.
11. Streitz, N. A., Hannemann, J., & Thüring, M. (1989). From Ideas and Arguments to Hyperdocuments: Travelling through Activity Spaces. In: Proc. of the 2nd ACM Conference on Hypertext (Hypertext '89), Pittsburgh, PA (November 5-8, 1989). NY: ACM. 343-364.
12. Waterworth, J. A., & Chignell, M. H. (1989). A Manifesto for Hypermedia Usability Research. Hypermedia, 1, (3), 205-233.
13. Waterworth, J. A., & Singh, G. (1994). Information Islands: Private Views of Public Places. In: Proceedings of East-West International Conference on Multimedia, Hypermedia and Virtual Reality. (MHVR'94) Moscow, Russia (September 14-16, 1994).

Integrated Architecture of Electronic Mall Systems — How Strategies, Processes and Organizations Influence Information System Design

Kai Bender

Dresden University of Technology
Institute for Information Systems
Mommsenstraße 13 • 01062 Dresden • Germany
Phone: 0351 4638432 • Fax: 0351 4638460
Email: kb7@inf.tu-dresden.de

Abstract. The design of information systems supporting virtual organizations and innovative work models is a strategic issue. However, many practitioners focus on the solution of technical problems. Although the term „architecture“ has already been subject to discussion, it has never really been defined. The paper introduces an architectural model consisting of the elements strategy, static organization structure, process structure, application structure, data structure, communication structure and infrastructure. It also demonstrates the application of this model to the development process of an electronic mall system. It becomes obvious that pre-defined patterns play a major role in all of the architectural components. Analysis and design patterns are not the only reusable components, they have just been the latest ones to be discussed. Patterns make the development of architectures more efficient and lead to better results.

Keywords. electronic mall, information system, architecture, organization, strategy, process, modelling, pattern

1 Introduction

Innovative work environments are significantly influenced by modern information technology. However, the value added to an organization by an information system depends on the ability of its designers and users to cope with an ever changing environment and to keep the system flexible. Many approaches to the fulfilment of these requirements have been undertaken, but most of the papers published are either not concrete or too focused on technological aspects. The emergence of the World Wide Web contributed to making these problems more obvious. It did not take very long for computer scientists and software developers to design and implement tools, that provided practitioners with the possibility to solve almost every problem of a technical nature. However, there still seems to be a lack of strategic concepts. In many cases management has not been able to identify the opportunities and threats arising from their web presence. Almost every company maintains a site but most of the enterprises do not really understand the necessity to do so. Neither are they able to quantify the profit accountable to the web as a new distribution channel. Instead, many companies try to compensate a lack of concepts and deep understanding with ever more complex technology. The most misunderstood term in this context has probably been „architecture“. Most software engineering experts are convinced that a proper information system architecture leads to higher efficiency of organizations. However, deep understanding is rare. Definitions reach from „the high-level structure of the system“ to „the sum of all the notions of a system“. If there is one attribute, that fits all the definitions, it is the word „vague“. At the department for information systems at Dresden University of Technology we have tried to find a precise definition of the term and we have applied our model to an electronic commerce project which is supposed to deliver a software that supports business on virtual marketplaces, one of the latest approaches to distributed or virtual organizations. We believe that this model is the first one to summarize which components an information system architecture should consist of.

2 Integrated Architecture – What does it mean ?

This chapter provides a means of describing information system architectures in their context. The resulting reference model is based on a paper by Krcmar (1990) which has been extended by its contextual elements. It is therefore called „integrated architecture“ (Fig. 1). The components of the model are presented here.

Information systems live. Their ability to fit both, the business itself and the technology available, is therefore especially relevant. But these two success factors are not independent, they influence each other strongly. Regarding information systems they are two poles between which the system has to be arranged. The component of an architecture that makes this arrangement possible is strategy. Enterprises work to fulfil targets like customer satisfaction, growth or shareholder value. If they are to succeed, they have to be developed over time (the term „business engineering“ has become popular for this). But change does not come by itself, it has to be planned laying out a strategy on how to act on the market. The tools for strategic planning are manifold. Value Chain Analysis is probably the most prominent method. It leads to the development of strategic programmes which are implemented conducting projects. As shown in Fig. 1 an architectural project usually delivers two structures: the static organizational structure and the structure of the processes working on it. They represent the basic business components and are the basis for IS analysis. However, many software engineers seem to ignore them or at least there common origin: strategy. Furthermore, technology itself is also subject to strategic decisions. A corporate strategy is the major parameter of an IT strategy. This leads to the conclusion that technology as well as business structure themselves have to be architectural elements. Remembering one of the vague – but actually not so bad – definitions mentioned above, architecture has to combine notions of a system. This includes the management’s (organization) and the programmer’s (infrastructure, i.e. technological aspects) view. During analysis of an organization the modeller learns about who the designated users of the system are. It becomes obvious that he has to lay out a communication model using e.g. context diagrams as a first step. When refining this model it might turn out that the different roles people play in the context of the system require different technological support. This is where the technological infrastructure gains importance. We will see that this analysis may even lead to the decision to use different platforms for the various user interfaces.

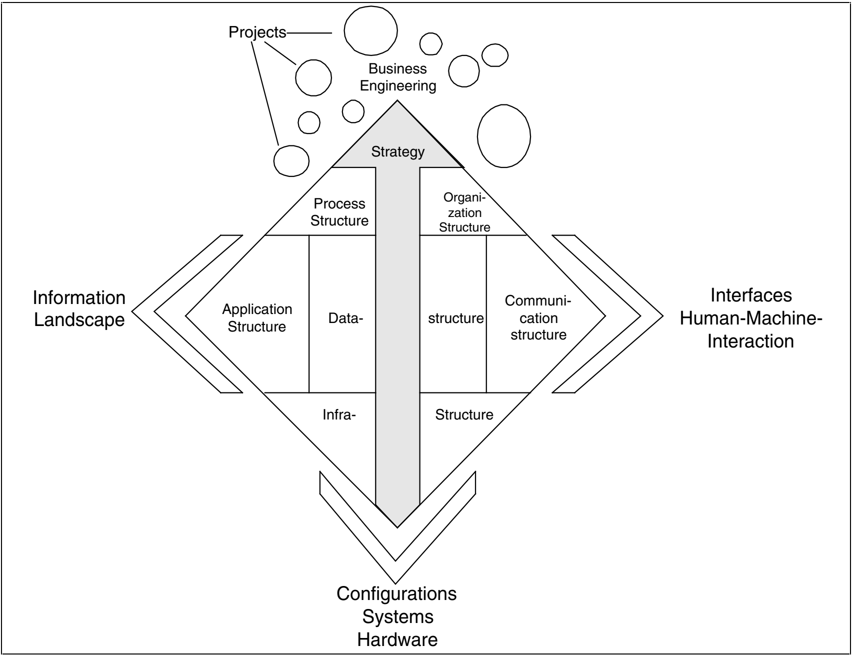


Fig. 1. Integrated IS architecture in its environment

Shifting the focus to application design the processes determined by strategy turn out to be the main architectural component. Tools for this step are at hand (e.g. Jacobson's use-case analysis) and there is an increasing number of books about pattern languages concerning IS models. Considering „cooperative buildings" this pattern approach is especially relevant since it originates from the field of architecture. Analysis patterns help to create a model that manages the basic concepts of the surrounding „information landscape" like communication partners, subjects, deadlines and resources. This model is usually documented using a method like UML. Usually, the application and communication structures require the storage of persistent data. Therefore a data structure model is also part of an architecture. Its modelling is straightforward and can be done using Entity Relationship Diagrams. It can be strongly influenced by the technological infrastructure since numerous large enterprises use legacy systems or have set up projects to introduce object-oriented databases.

3 Electronic Mall – Adding value for SMEs

The immaturity of today's commerce oriented web applications may in many cases turn out to be very costly. Although the products offered may fit their market well and may even be perfectly suitable for distribution through conventional channels they fail to generate additional revenue when presented online. However, researchers and practitioners from all over the world keep pointing out that the opportunities offered by the Web outnumber the threats by far. But these opportunities are not substantial as long as no structured approach to the integration of web services into the company's business and IT portfolio is applied. Especially small and medium enterprises (SMEs) will not be able to invest much into an area where not even the methods of evaluation are clear. It becomes more and more obvious that the rules for laying out marketing plans using classic advertising do not apply to internet business. One main reason for this dilemma is the complete isolation of a start-up web site and the impossibility of „contact by chance", a prerequisite for conventional media plans. Usually an additional campaign is needed to promote a web site. Again, this is not affordable for many SMEs. A possible way out of this dilemma is the concept of concentration. Many retailing businesses prefer to be present in a shopping mall rather than running a small shop on their own. This is because consumers like to refer to such a mall as „their place". They are aware of 90 per cent of their demand being satisfied by shopping centers. Regular customers know the way how to get there, they know the infrastructure (e.g. parking lots) and the „feel" of it. Of course, this has a certain number of organizational consequences. The retailer has to rent a store from the provider and there is little or no room for negotiations concerning prices. Furthermore his design options are limited since the whole mall has an underlying corporate identity which has to be harmonized with the retailer's design. He may even face restrictions concerning his own assortment of goods and services. It is not going to be feasible placing a designer store next to a cash & carry – market. These rules apply to electronic commerce as well. Small businesses who are not very well known but who may become successful niche players in their specific market can compete with enterprises bearing global reputation if they rent a store at an electronic mall (e-mall). An e-mall is a virtual marketplace for commercial and social life that supports supply and demand on good and service markets. There are three major parties involved in this scenario:

- the mall provider, supplying the hard- and software infrastructure and handling the technical administration;
- the content providers, offering their services in separate stores within the system; and
- the customers, gaining information about and buying goods and services, thus generating the critical mass needed to run the system.

These parties represent three customer segments whose needs have to be analysed before designing and implementing an according software. The results of this analysis are the origin and main parameter of the integrated architecture being described in the following chapter.

4 The Project – The Architecture

The project team working on the system to be introduced consists of information management specialists and software developers from several institutions. These institutions are:

- The Dresden University of Technology, Germany, especially the Institute for Information Systems;
- The IST GmbH, Dresden; and
- The DVZ Mecklenburg-Vorpommern GmbH, Schwerin.

The aim of the project is to develop an e-mall software that extends the functionality of most existing systems.

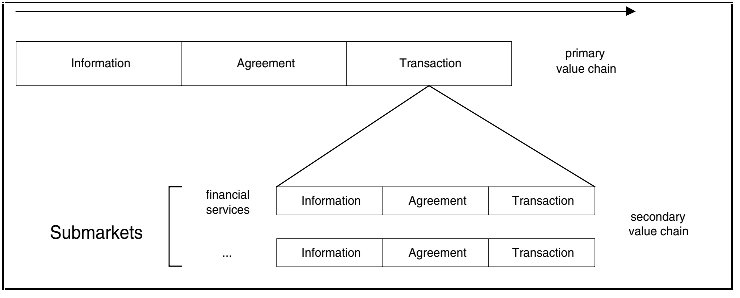


Fig. 2. Primary and secondary value chains

The core element of the architecture, according to the model introduced in Fig. 1, is strategy. When talking about strategies it is important to consider the activities adding value. The general value chain model by Porter is useful but it is not fine-grained enough to be applied to this project. A special E-Commerce value chain has been defined by Schmid (1995) (see Fig. 2). Each sale is an element of the second phase of a process consisting of the steps information, agreement and transaction. Understanding the high-level process better we can now consider the consumer segments and try to analyze the customers‘ expectations. Very obviously, the customers expect:

- Higher flexibility;
- Independence from time and location;
- Lower prices.

The advantages resulting from online shopping have to be communicated to the customer in an early stage, i.e. in the information phase. This imposes the need upon the content providers to restructure their processes in phase two and three in a way that allows them to lower their prices, thus making online shopping more attractive. But where does the potential for lower prices come from ? It has to come from the lower cost of the distribution channel itself. But cost can only be cut if substantial parts of the process – not just the information phase - are conducted using the web. In a nutshell, the content providers expect:

– Straight processes using the web almost exclusively;
– Higher revenue without cannibalizing other distribution channels;
– Low primary investments.

Obviously, the mall provider‘s needs have to comply to this. A mall gains attractiveness, when its trading volume is high and many customers attend it on a regular basis. Customers will show this behaviour when their needs are fulfilled. A high number of stores will lead to improved customer satisfaction. The mall provider will be able to raise this number by keeping primary investments for content-providers low. So the mall provider wants:

– High trading volume;
– Low administrative cost;
– Consistent look & feel.

These strategic considerations are just an excerpt of the whole marketing concept but they demonstrate its influence upon the software development process sufficiently to draw the conclusion that strategy itself must be regarded as a part of information system architecture. According to the integrated architectures‘ model static organization structures and the processes working on it are derived from strategy. Fortunately, an e-mall does not have to support a complex organization as it would be required in decision support or management information systems. However, there are some considerations to be made. The first one results from the fact that customers may well be private or business customers. This is important since private customers buy and pay goods for themselves whereas business customers (companies, in fact) need a representative, a so-called purchasing agent. Similarly, a content provider needs to delegate administration of customers, goods and stores to an administrator. Furthermore, there has to be a super administrator who is able to introduce other administrators. Regarding the processes working on the organization structures defined above the value chain is very important. It lays out one of the major processes that occur so that quite all further analysis is a refinement of the basic market transaction value chain. There are a lot of methods on how business processes should be modelled best. Many of those are derivates of structured analysis, some add real additional information like resource usage. In many cases the last step of analysis is done using a method like state machines or petri nets.

This completes the short overview over the architectural components strategy, organizational structure and process structure. Recalling the model being introduced in Fig. 1 there is another architectural ‚pole‘ influencing the information system: infrastructure. The relevance of infrastructure differs strongly from project to project. In single-user terminal systems it is practically zero. In multi-user distributed systems like the one focused here it is significant. Usually the visualization of an infrastructure is done in an informal way. However, there are recurring patterns that can be reused. One of these is the three-tier architecture that consists of a data-management tier, a distribution tier and an application tier. In this system we have extended the capabilities of this structure so that there may be even more than one distribution tier. Since the system is to run on the web it has to be implemented using platform independent technology. The data management system to be used is a relational database. At the data management level, the conversion of table-structured data into objects is performed. The object distribution layer(s) make the classes accessible from each and every point throughout the web and assure consistency. The application level on the client side contains the functionality of the front-end.

Having conducted the analysis of strategic and technological issues the modelling of the software system itself, i.e. the middle level of the model in Fig. 1, can begin. Therefore it is necessary to consider the communication structure first. The results achieved in the context of the organizational structure can help here. Terminators are derived from the static organizational structure, information flows originate from the processes. Using this approach a context diagram can be developed (see Fig. 3).

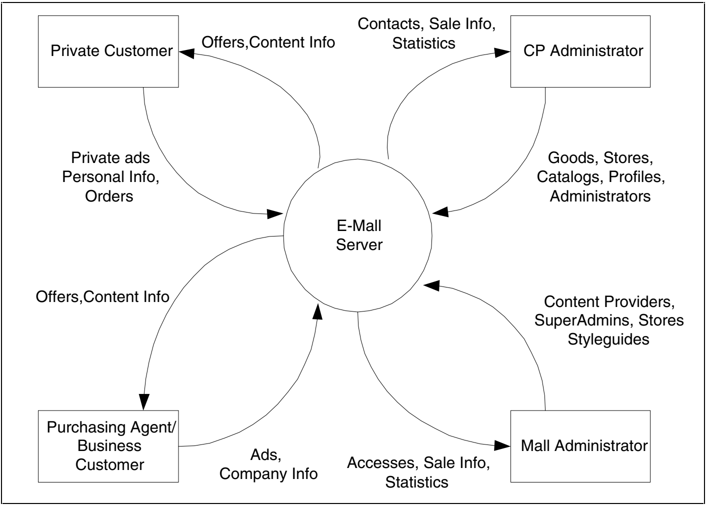


Fig. 3. Context diagram

In this project the combination of strategic concepts, infrastructure and context information led to the conclusion that customers and administrators should obtain separate front-ends while working with the same back-end system.

The next step is the development of the application structure itself. This is a phase in the architectural development process that most software engineers would have suggested coming first. But now that strategies, infrastructures and communication structure are already outlined it gets much easier to conduct further analysis. The modeller can start using the terminators of the context diagram as first object candidates. Not all of these will turn out to become real classes in program code but the terminators will prove very helpful in many cases. Furthermore, the value chain's phases should be reviewed. Process steps themselves may be significant entities. Are these steps documented as persistent data ? Many questions like these arise from the other components of the architecture. The last missing architectural component is the data structure. This structure is usually derived from the application structure. It is modelled using the Entity-Relationship approach. Data structures are especially interesting in large distributed systems since referential integrity and persistence of information is a very critical issue. Having conducted all these steps the architecture is complete. It consists of a number of highly comunicative but still formally precise models which can serve as a means of documentation and as a guideline to successful design and implementation.

5 Conclusions and Outlook

Each of the architectural sub-models uses a well-known notation. Due to this, modellers have started to think about reusing parts of their models. In recent years this approach has become popular in IS modelling, too. Design and analysis patterns emerged and were able to convince software developers from all over the world that they were able to raise productivity and quality equally. This paper shows that there are patterns in every part of an architecture. Organizational structures use patterns like „functional organization“ and „divisional organization“. Strategies use many patterns, among them „penetration“ and „skimming“ as pricing strategy patterns. There are patterns in infrastructures (referred to as „3-tier-architecture“ or „pipes-and-filters“-architecture, and so on). And of course, there are now patterns for application, data and communication structures, e.g. the publications by Fowler (1997), Hay (1996) or Coad *et al.* (1995). If projects succeed without making all architectural components explicit, it is because of project management doing things implicitly right. But in a technically and conceptually challenging environment like Electronic Commerce such approaches are not very likely to be successful. Architectures have to be available to guide analysts, developers, project managers and designated users and they have to consist of the structures demonstrated making use of patterns, thus taking advantage of the experience originating from hundreds of projects in the past.

References

1. Bender, K. (1997). Electronic Mall: Anforderungen, Strukturen, Lösungen. Presentation at BIK 97, Leipzig, 17.9.1997, http://141.76.55.200:8080/Mall/Praesentation.doc
2. Böttcher, R., Gärtitz, U., & Bender, K. (1997). ELMA – ein elektronischer Marktplatz. In: DVZ Info, magazine of Datenverarbeitungszentrum Mecklenburg-Vorpommern, Schwerin, 2, 9-11.
3. Buschmann, F., Jäckel, K., & Meunier, R. (1995). Software-Architektur mit Entwurfsmustern. In: Conference Proceedings of the OOP 95, Munich.
4. Coad, P., Mayfield, M., North, D. (1995). Object models: Strategies, Patterns and Applications. Englewood Cliffs: Yourdon Press/Prentice Hall.
5. Fowler, M. (1997). Analysis Patterns: Reusable Object Models. Addison-Wesley, Reading.
6. Hay, D. C. (1996). Data model patterns: conventions of thought. New York: Dorset House Publ.
7. Krcmar, H.(1990). Bedeutung und Ziele von Informationssystem-Architekturen. In: Wirtschaftsinformatik, 32 (5), 395-402.
8. Scheer, A.-W, (1991). Architektur integrierter Informationssysteme. Berlin.
9. Schmid, B.(1995). Electronic Mall: Banking und Shopping in globalen Netzen. Teubner.

An Agent-based Telecooperation Framework

Albrecht Schmidt, Alexander Specker, Gerhard Partsch,
Michael Weber, Siegfried Höck

Department for Distributed Systems
University of Ulm, Germany
Email: [aschmidt, aspecker]@hydra.informatik.uni-ulm.de,
[gpartsch, weber, hoeck]@informatik.uni-ulm.de

Abstract. As the amount of information and communication increases dramatically new working environments must provide efficient mechanisms to maximize the benefits of these developments. In this paper a telecollaboration environment based on agent technology is proposed, which could be used as an information infrastructure for cooperative buildings or virtual enterprises.
The number of communication and information services increases rapidly in number and complexity. Therefore mediating components between users and services are required. In the environment being described it is suggested to deploy a personalized agent cluster for each user and network wide directory, broker, and trading services.

The agent cluster acts as a surrogate for the user in the system. In each cluster a variable set of personalized agents is aggregated according to the requirements of the user. Exemplarily the architecture and functionality of a communication agent as one part of an agent cluster is described.

Keywords. telecooperation, Internet, agent technology, personalized agents, computer supported cooperative work (CSCW), multimedia, communication, broker, trader

1 Motivation

Importance of Information and Communication. In the age of proliferating information and communication systems, information is becoming a production factor of great importance. Nearly all private and business processes rely more and more on the timely deliverance of information and data. Without intensive communication and cooperation these processes are hardly manageable. To accomplish this task an effective information, communication and collaboration environment is vital. Such an environment should be the foundation for cooperative buildings or other new forms of work environments, such as virtual enterprises, telecenters or -houses, or virtual (home-)offices.
Quality of Information. As the amount of information delivered to our homes or offices is becoming larger, the time we spend on reprocessing and filtering this extensive information is increasing to a hardly manageable extent. The goal is to extract the

useful and relevant information out of the available data in a cost and time effective manner.

Multiple Media. The media choice is traditionally not made by the receiving side but by the sender. The person that receives the information in this model has no straightforward way of influencing the choice of media and is therefore not able to make an optimal selection of the communication media according to her needs.

Synchronous Communication. Ideally all communication has a synchronous character. Delayed deliverance of messages should not be the result of the underlying transportation system but should be on purpose and adjusted to the users needs. The user wants to receive data not always as fast as possible contrarily he wants to be informed at that point in time that is best suited to help him solving his tasks (Maes, 1997b).

Here synchronicity means, that messages are delivered to the user´s agent as fast as possible. If the user is not ready to receive the information, the agent holds messages back. If the agent itself is not reachable, due to network failures for instance, store and forward mechanisms in the framework are exploited.

Addressing the above mentioned problems we present in this paper an architecture and environment utilizing agents for personal communication and information in collaborative processes. These agents residing in the network act as intelligent, personalized and synchronously accessible partners of a real person. The agents optimize the communication and information process both of the individual person and the overall work process. Agents being specialized for different tasks form an agent cluster to represent their user in his various communication and collaboration tasks.

2 System Architecture

The system architecture of the telecooperation framework can be divided into two logical aspects interconnected closely with each other. In this section the first aspect the information exchange and coordination between the system components and the agents will be described. The following sections will explain the design and cooperation of the agents themselves. These agents are used to interact with the user, offer a homogeneous user interface and support the work between different users supported by external service components distributed over the network , see Fig. 1.

The agents can contact these services to use their additionally specialized functionality like teleconference scheduling or workflow management support. External services can offer more easily highly complex and efficient services than the agents are able to implement. With these distributed service components increased functionality needs are easily maintainable by updating and adapting these service components. As the main part of functionality resides inside the service components, the agent-side complexity can be lower and less task specific. Agents just have to be extended to implement an interface to a specific service component.

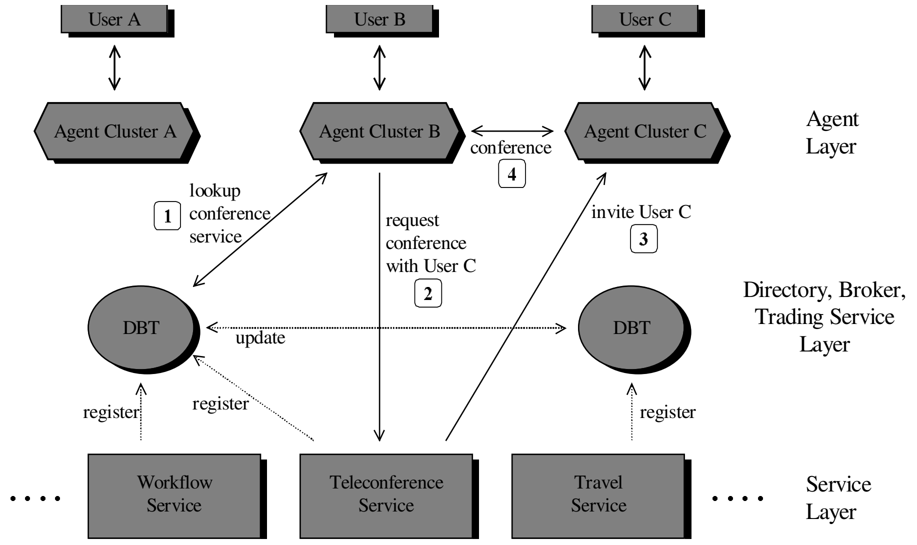


Fig. 1. System architecture

Inside the service layer of the system all task specific knowledge is concentrated, this makes an efficient support of multiple user agents possible. Services such as Teleconferencing Service, Workflow Service, Meeting and Conference Scheduling Service, Database Service, Gateway Service and Electronic Marketplace Service can be offered in the network by third party service providers or by the IT-department of the user's company. Depending on the task the service can be provided by humans or intellignet systems. The system components in the telecooperation framework are designed flexible and open to integrate additional services at any time.

The directory service is used to deliver static information on service components and the location and addresses of agents, brokers and traders. The deployment of broker and trading services in a telecooperative environment as shown by Höck *et al.* (1997) is used here. The broker and trading functionality together with the above mentioned directory service serves as the location, negotiation and binding foundation of the presented telecooperation environment.

3 Agent Cluster and Functionality

To implement an optimal participation of each user in the cooperative process the agent paradigm is deployed. Each user is represented by an agent cluster in the system. In the cluster a variable set of agents is aggregated, see Fig. 2.

Each agent has its own special task. E.g. the diary agent (DA) is keeping track of all appointments and makes the scheduling for the user. The workflow agent (WA) coordinates the interaction with other participants taking part in a workflow as well as with the workflow service. The remembrance agent (RA) is an active notebook to remind the user. A communication agent (CA) handles all communication on behalf of the user.

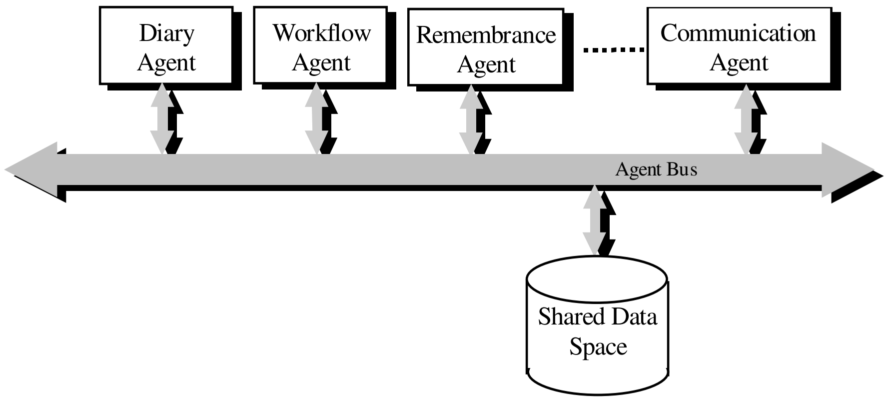


Fig. 2. Agent cluster

The main design goals for the agent cluster are described below. These features are of major importance to gain an improved productivity by using agents.

Personalization. The agents are personalized to the needs of the user. Agents have a certain knowledge about their users such as *she does not like meetings before 11am*, *he can not stand video conferences*, or *she prefers travelling by train*. The fact that agents are personalized give users the feeling that the agent is intelligent and caring.

Ability to learn about the user. To improve personalization it is necessary that the agent can learn likes and dislikes of the user by monitoring their behavior.

Synchronicity. Due to the fact that the agents are the surrogate of the user within the system, they are always accessible and therefore synchronous communication between agents of different users is always possible even if the user is not available.

Privacy. To provide privacy, and that is a very important issue when using personalized agents with extensive knowledge about their users, protocols are deployed that can determine who the partner is you are talking to and which information this partner should be able to see and which not.

Intra-cluster agent communication. The agents within a cluster can communicate with each other in an unrestricted way. Thus the user can be supplied with the information and communication at the right time and in the appropriate form. Through agent cooperation within the cluster the information load on the user can be reduced significantly. An agent bus (a software bus) and a shared data space, as shown in Fig. 2 is used to enable intra-cluster communication.

Inter-cluster agent communication. To perform their tasks agents must have the ability to communicate with other agents that belong to other users. As a general communication protocol the knowledge query and manipulation language, KQML described by Finin *et al.* (1993), is suggested for this purpose.

4 Agent Architecture and Functionality

The whole functionality to support the user is split up in separate entities each being supported by an agent. This way the complexity of a single agent is reduced. The architecture allows each user to compose his own set of agents in his cluster. The functionality of one agent results from the mechanisms provided by the agent, the interaction between agents, and from communication between agents and services.

4.1 The communication agent

To make it more concrete the communication agent is discussed in more detail in this section. This agent is deployed to handle all communication on behalf of a user. In Fig. 3 the architecture of the CA is depicted.

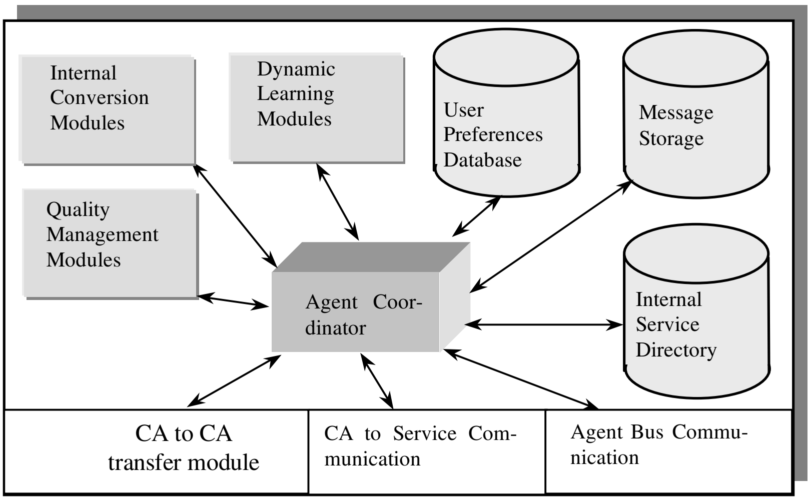


Fig. 3. Agent architecture

The knowledge about the user is stored in the *User Preferences Database*. The *Dynamic Learning Module* is monitoring the behavior of the user and improves the personalization of the agent. Media conversion can be provided by the *Internal Conversion Modules* or by external services. Addresses and parameters of often used services are cached in the *Internal Service Directory*. Incoming and outgoing messages that could not be delivered yet are collected in the *Message Storage*. In the *Quality Management Modules* the logging and acknowledging of the communication streams is performed. The agent also provides different interfaces for communications to other agents and services.

The following features are of major importance to the developed communication agent.

Choice of media. In the proposed architecture the freedom to chose the communication media is given to the sender as well as to the receiver. This has the advantage that the user can always take the most appropriate way to communicate according to his situation.
Active agent. The agents are active components. The interaction can be triggered by the agent as well as by the user. Due to the fact that the CA has knowledge about the user and also communicates with other agents in the cluster the support for the user can be improved significantly.
Quality management. By using a synchronous CA it is possible to provide different levels of acknowledgement protocols. If the messages and the acknowledgements are authenticated by the senders the logging of the communication can be used for quality and history management or for legal issues.
Freshness of messages. To reduce the information load on the user a *best before* date is introduced into the messages.
Ownership of messages. Messages are owned either by the sender or by the receiver; they are never owned by the transport system. The system provides two general way to send messages. First the traditional way: the whole message is transmitted to the receiver and here the message is owned by the receiver after sending. The second way is to send only a link to the message. Then the message is still owned by the sender and can be modified or deleted till the receiver fetches the message.

5 Related Work

Agent technology and its usage in the Internet environment is quite popular in present research. It is beyond the scope of this paper to give a complete survey of agent technology, but the following selection provides some fundamentals of agent technology, describes a choice of research projects using agents in the web, and by this mentions work that inspired the described system.

At MIT Media Lab the software agent group is investigating agent technology in different projects (Rhodes, 1996; Lashkari *et al.,* 1994). Pattie Maes (1997b) states the following features of agents that are relevant for our work, too. “Software agents differ from current-day software in that they are

(1) proactive (taking the initiative to help the user by making suggestions and/or automating the more mundane tasks the user normally would have to perform),
(2) adaptive (learning the user’s preferences, habits and interests as they change over time),
(3) personalized (customizing their assistance according to what they learned about the user), and
(4) autonomous (operating with minimal supervision on behalf of the users)“.

Falchuk *et al.* (1997) at the University of Ottawa are working on mobile and intelligent agents targeting the problem of information retrieval and computer-aided instruction. A news gathering agent and a telelearning agent are introduced. They also address problems emerging with mobile computing such as address migration, heterogeneous networks, or portability (Ford *et al.,* 1997). An agent based news filter is implemented as a prototype. Their work is mainly concentrated on resources located in the Internet. Due to the focus on mobile agents most of the work concentrates on asynchronous tasks.

The support of mobile users is targeted by researchers at ECRC. Chevalier *et al.* (1997) have developed a technology called Mobile Service Agents. They developed the idea to use an agent as a local representative while the user is not connected to the network. In this way interactive working can be done even when the user is temporarily disconnected.

Petrie (1996) analyzed the conflict between the client/server WWW paradigm and the peer-to-peer agent model. The usage of KQML-like agents and their compatibility with the web is discussed.

The concept of a software bus called InfoBus for JavaBeans is in the process of specification at Sun Microsystems (1997). The idea is to define a small interface which allows different components (JavaBeans) to exchange information in a structured way. The bus is proposed as an asynchronous and symmetric communication system between components without the need for a master component. The protocol is the controlling component. Corba also represents a middleware technology based on the software bus concept; Siegel (1996) shows an implementation of several interworking ORBs.

6 Conclusion

The described system supports the work of users by adaptive system functionality through the use of a triple layered service and agent infrastructure. In this paper the primary focus was drawn on the reduction of communication and information load. This is achieved by analyzing, extracting and optimizing the data flow in accordance with the situation and environment the user is in.

Users can access different services in a uniform way by employing their personal agents. These agents can interact with other agents or services. To locate and access services and agents in a heterogeneous environment brokers and traders are used. Due to this architecture agent-side complexity can be fairly low. Dynamic changes of services and users, such as new access protocols, changing locations, and additional functionality are transparent.

The exemplarily demonstrated communication agent acts as a synchronously accessible surrogate of the user in the network. It provides the mechanisms for the conversion of different communication forms and therefore enables the sender to contact the receiver always in an appropriate manner, without imposing a common communication medium.

References

1. Höck, S., & Weber, M. (1997). A Telecooperation Framework Based on Broker and Trading Services. In: Proceedings of the 1st Workshop on Enterprise Distributed Object Computing, EDOC'97, Brisbane.
2. Maes, P. (1997a). MIT Media Lab, Software Agents Group: Research. http://agents.www.media.mit.edu:80/groups/agents/research.html
3. Rhodes, B. (1996). Remembrance Agent: A continuously running automated information retrieval system. In: Proceedings of the 1st International Conference on the Practical Application of Intelligent Agents and Multi Agent Technology, London, 487-495.
4. Lashkari, Y., Metral, M., & Maes, P. (1994). Collaborative Interface Agents. In: Proceedings of AAAI '94 Conference, Seattle.
5. Falchuk, B., & Karmouch, A. (1997). A Mobile Agent Prototype for Autonomous Multimedia Information Access, Interaction and Retrieval. In: Proceedings of Multimedia Modeling '97, Singapore.
6. Ford, B., & Karmouch, A. (1997). An Architectural Model for Mobile Agent-based Multimedia Applications. In: Proceedings of Canadian Conference on Broadband Research '97, Ottawa.
7. Chevalier, P.-Y., & Thomsen, B. (1997). ECRC - Mobile Service Agents. http://www.ecrc.de/research/dc/msa/
8. Petrie, C. J. (1996). Agent-Based Engineering, the Web, and Intelligence. IEEE Expert. http://cdr.stanford.edu/NextLink/Expert.html
9. Sun Microsystems. JavaBeans InfoBus draft specification (v0.04A, Aug. 21 1997) http://java.sun.com/beans/infobus/ibspec.html
10. Finin, T., Weber, J., et al. (1993). Specification of KQML Agent Communication Language. DARPA Knowledge Sharing Initiative.
11. Interview with Pattie Maes (1997b). Pattie Maes on Software Agents: Humanizing the Global Computer. IEEE Internet Computing July-August (1997b)
12. Siegel, J. (1996). CORBA: Fundamentals & Programming, Wiley.

The Co-operative Evolution of Buildings and Cities

John Frazer

School of Design
Hong Kong Polytechnic University
Kowloon, Hong Kong, China.
Email : sdfrazer@polyu.edu.hk

Abstract. This a position paper outlining the way thinking about co-operative buildings has developed over the last 30 years. It does not attempt to review the field in an objective manner but summarises the particular viewpoint of the author by reviewing selected co-operative projects. Starting briefly with the author’s final year thesis, the paper touches on projects for Cedric Price and Walter Segal with contrasting ideas about co-operation. The paper then expands on the concept of co-evolutionary theory including the co-operative evolution of buildings with each other, with the environment and with the inhabitants. It concentrates on the most recent co-evolutionary projects for buildings and cities. It describes the Groningen experiment which demonstrates these principles with a model which allows the co-operative development of the city with the "collective social ambition of the inhabitants." The paper ends with a note about the "Talking Cities" project for global co-operation in the evolution of urban form. These examples are presented as a series of "vignettes" or glimpsas at history.

Keywords. co-operative buildings, evolution of buildings, evolution of urban form, autotectonics, genetically coded building, generator, co-evolutionary cities, interactivator

Vignette 1: Background

My final year thesis at the AA in 1969 was entitled Autotectonics: The choice of choice. This was my first excursion into the field that is now being referred to as co-operative buildings. I coined the word "autotectonics" in 1965 as a reaction to "architecture" - where arch has connotations of power (archdeacon, archdevil) and substituted auto with connotations of self (autonomy, automobile). The "choice of choice" part of the subtitle was intended to suggest that architecture current architectural thinking was starting to at least consider choice, but that the wrong set of choices was being offered like the choice of a menu but in the wrong restaurant. The project introduced the idea of genetically coded building descriptions and the idea of user interaction in the design process and subsequent reorganisation of the building in use and drew on my student projects of the previous few years. The genetic code of the building was manipulated in a primitive computer model (Frazer & Connor, 1979).

Later at Cambridge University I had access to computer power and software expertise which allowed this to be turned into a working demonstration. This project is described in the book An Evolutionary Architecture as well as several papers (Frazer, 1995a).

Vignette 2: The Generator project

One of the formative thinkers about co-operative building must be Cedric Price. His work is dominated by social pre-occupations which are epitomised by the concept of co-operation. In 1978 Cedric Price asked us to work as computer consultants on the Generator project (Frazer, 1979). The Generator consisted of a kit of parts which enabled enclosures, gangways, screens and services to be arranged on a site (a clearing in a forest in Florida) to fulfil the requirements of the users, the Gilman Paper Corporation. It was proposed to grid the site with foundation pads and to provide a permanent mobile for moving components, thus involving the co-operation of the users of the centre in its organisation.

The computer program was developed to suggest new arrangements of the site in response to changing needs. Our concern that components might not be where we expected them to be prompted our decision to turn the whole site into a vast working model. By embedding electronics in every component and making connections to the foundation pads we effectively made the site into a gigantic reconfigurable array processor, where the configuration of the processor was directly related to the configuration it was modelling. At this stage, the controlling processor could be dispensed with, as there was more than adequate processing power distributed throughout the structure of the building. The building thus became intelligent , as we explained it in a letter to Cedric Price in 1979. This led to some amusing headlines: Birth of the Intelligent Building, Thinking for Fun and The Building that Moves in the Night (Sudjic, 1981). Unfortunately the term intelligent building has now been devalued to mean any building with provision for information technology! The term intelligent structures , on the other hand, has acquired considerable meaning and is now the subject of serious books and a journal. The more interesting co-operative nature of the proposed building and its users did not attract so much comment.

One worry was that the building would not be changed enough by the users because they did not see the potential to do so. We consequently suggested that a characteristic of intelligence, and therefore of the Generator, was that it would register its own boredom and make suggestions for its own reorganisation (Greig, 1988). This is not as facetious as it may sound, as we intended that the Generator would learn from the alterations it made to its own organisation, and coach itself to make better suggestions. Ultimately, the building itself might be better able to determine its arrangement for the users benefit than the users themselves. This principle is now employed in environmental control systems with a learning capability.

Vignette 3: The Walter Segal self build and self design system

Walter Segal is another Arhcitect whose work shows a profound concern with co-operation and user involvement with design. Walter Segal developed a timber-framed building technique suitable for self-builders. It was not a building system in the sense of a kit of parts, but rather a discipline in the efficient and economic use of materials. It used a 2ft grid with a 2in structural zone which allowed the economic cutting of panels from standard 8ft by 4ft sheets. Lewisham Council s promotion of self-build housing associations on a number of awkward sites resulted in a range of single- and two-storey houses. Segal was anxious to encourage his self-builders (McKean, 1989) to become designers as well: he encouraged them to visualise the work, using first matchsticks to represent the 2ft module and then a slotted base board and panel model. He found, however, that the self-designers required a great deal of help in interpreting their models.

We built an electronic version of the panel model with an 8-bit code on every panel and fitting which allowed 128 different panels, door and window combinations, taking into account door swings, etc. A controlling processor scanned the board and interpreted the plans (two storeys were built side by side). Plans and three-dimensional views could then be displayed, areas calculated, costs determined and structural frame drawings produced. In effect the program incorporated not only Walter Segal's design rules but much more of his expertise. As a result, people without any knowledge of architecture or computers could design a house by building a simple model. The working system was successfully demonstrated to Walter Segal in his house in 1982 (Pearman, 1985). He was delighted, but his untimely death prevented him from experimenting further with the system. The project was first shown publicly in Washington at the Computer Graphics in the Building Process Conference in March 1982 and then at the CAD'82 Conference (Frazer, 1982). The working model was exhibited at the Barbican and at the Design Council and featured in the Spectrum television programme in 1984. One of the lessons learned from the Segal project was that there was real potential for client and user involvement and co-operation in design.

Vignette 4: Evolutionary Design

The theory of evolutionary design is described in An Evolutionary Architecture. A significant part of the theory involves the co-operative evolution of structure and environment and the co-operative development of different buildings in an urban context.

Evolutionary Design involves using the virtual space of the computer in a manner analogous to evolutionary processes in nature. It attempts to emulate the unselfconscious design processes of vernacular architecture. Whilst the techniques described can be achieved with relatively simple design problems such as yacht design, architectural problems still require computing power in excess of what is yet readily available and are thus on the very cusp of being realisable.

In an attempt to achieve in the built environment the symbiotic behaviour and metabolic balance that are characteristic of the natural environment, it proposed the evolutionary model of nature as the generating process for architectural form. The profligate prototyping and awesome creative power of natural evolution are emulated by generating virtual architectural models which respond to changing environments. Successful developments are encouraged and evolved. Architecture is considered as a form of artificial life, subject, like the natural world, to principles of morphogenesis, genetic coding, replication and selection.

Architectural concepts are expressed as generative rules so that their evolution and development can be accelerated and tested by the use of computer models. Concepts are described in a genetic language which produces a code script of instructions for form-generation. Computer models are used to simulate the development of prototypical forms which are then evaluated on the basis of their performance in a simulated environment. Very large numbers of evolutionary steps can be generated in a short space of time and the emergent forms are often unexpected.

These techniques had previously been limited to easily quantified engineering problems. Only now is it becoming feasible to apply them to the complex problems associated with our built environment. To achieve this it is necessary to consider how structural form can be coded for a technique known as a genetic algorithm, how ill-defined and conflicting criteria can be described, how these criteria operate for selection, and how the morphological and metabolic processes are adapted for the interaction of built form and its environment. Once these issues are resolved, the computer can be used not only as an aid to design in the usual sense, but also as an evolutionary accelerator and a generative force.

Genetic techniques for design model inner logic, rather than external form, and the exhibition afforded a glimpse of a future architecture as yet evolving only in the imagination of a computer.

How an evolutionary model works

The evolutionary model requires that a design concept is described in a genetic code. The code is then mutated and developed in a computer program into a series of models in response to a simulated environment. The models are then evaluated in that simulated environment and the code of successful models is selected. The selected code is then used to reiterate the cycle until a particular stage of development is selected for prototyping in the real world.

In order to create a genetic description, it is first necessary to develop a design concept in a generative manner capable of being expressed in an a variety of forms in response to different environments. This is a manner in which many designers already work in the sense that they have a personal set of strategies that they adapt to particular design circumstances. This strategy is often very pronounced and consistent to the point where a designer's work is instantly recognised.

The co-evolutionary model

This was a collaborative research project involving both the University of Ulster and the Architectural Association. In the first stages the team at the Architectural Association in London had developed a theoretical model of an evolvable environment. For the example described here, Manit Rastogi of the Diploma Unit 11 at the Architectural Association developed a working interactive computer version and teamed up with Peter Graham from Ulster to produce a dynamically evolving model for the exhibition in London and the Internet experiment.

The model is organised by using a multiple hierarchical approach and a datastructure which is recursively self similar. The simulated environment in which evaluation takes place is modelled in exactly the same terms as the evolving structures. The environment and the structure not only evolve in the same dataspace, but can co-evolve. Moreover competitive structures can also evolve in the same space. Environment in this case includes user response and is modelled with virtual societies. The environment has a significant effect on the development of the concept using a genetic design language. Genetic algorithms are used to perform the selection and normal crossover and mutation are used to breed the populations.

The model consists of an endless array of data points which collectively constitute a dataspace. Each point in the dataspace is intelligent in the sense that it knows where it is and why it is there and it has a clear awareness of the spatial relationship of its neighbours. The laws of symmetry and symmetry breaking are used to control the development of the model from the genetic code. Information flow through the model takes the form of logic fields. Externalisation of this datastructure is process driven by modelling the process of form generation rather than the forms themselves.

The model is based on the sequential evolution of a family of cellular structures in an environment. Each cellular structure begins development from a single cell inheriting genetic information from its ancestors and from a central gene pool. Each cell in a cellular structure contains the same chromosomes which make up the genetic code. The cells divide and multiply based on the genetic code script and the environment with each new cell containing the same genetic information. The development process of each member of the family consists of three parts - cellular growth, materialisation and the genetic search landscape. A genetic algorithm is used to ensure that future generations of the model learn from the previous ones as well as provide for biodiversity during the evolutionary process.

The datastructure of the model is based on a universal state space or isospatial model where each cell in the world has a maximum of 12 equidistant neighbours and can exist in one of 4096 states, the state of a cell being determined by the number and spatial arrangement of it's neighbours.

The local environment of a cell in the world can thus be coded in a 12 bit binary string. The growth and development of the cellular structure is controlled by chromosomes.

Chromosomes are generated by either being sent in by any remote user, an active site or as a function of selection, crossover and mutation within cellular activity and are maintained in a main chromosomal pool. The physical environment determines which part of the main chromosome pool becomes dominant. The local environment of each cell then determines which part of the genetic code is switched on. The cell then multiplies and divides in accordance with that genetic code.

As cellular division takes place, unstable cells are generated. In the next generation this leftover material creates a space of exclusion within the cellular space. This space of exclusion interacts with the physical environment to create a materialisation of the model. Boundary layers are identified in the unstable cells as part of their state information and an optimised surface is generated to skin the structure. This material continues to exist throughout the evolution of the model and will initially affect the cellular growth of future generations.

The selection criteria in the model is not defined but is an emergent property of the evolution of the model itself. A genetic search landscape is generated for each member graphically representing the evolving selection criteria within the model based on the relationship between the chromosomes, cellular structure and the environment over time. Form, or the logic of form, emerges as a result of travelling through this search space.

Once chromosomal stability has been achieved, the parent cellular activity is terminated. The final cellular structure, the materialisation and the genetic search space are posted out. A daughter cellular activity is then initiated from a single cell. The fittest chromosomes from the parent generation are bred using selection, crossover and mutation and combined with the new list of dominant chromosomes from the main chromosome pool to form a new chromosomes set for the daughter generation. The development process is then repeated for the daughter generation (Frazer, 1996b, Frazer & Frazer, 1996)

The datastructure for this technique was first presented in Tokyo in 1992 at the conference on Visual Computing (Frazer, 1992)

Vignette 5: Co-operative evolution on the Internet: The Interactivator

In January 1995 we constructed an exhibition on An Evolutionary Architecture (Frazer, 1995b) for the Architectural Association Gallery in London. The centrepiece to the exhibition, The Interactivator (Frazer, Rastogi, & Graham, 1995, Frazer, Graham & Rastogi, 1995), as an evolving environment which was planned to respond to both interaction from the exhibition visitors and the atmosphere in the exhibition space. Visitors were to interact by proposing genetic information which would influence the evolution of the model. Sensors in the exhibition space also affected the evolution of the model with data on temperature, humidity, noise, smoke and so forth. We extended this concept to allow co-operation on the Internet in three ways: First, by using the Internet to allow virtual visitors to input genetic information to the model just like actual visitors. Second, by allowing the program of the model to be downloaded to remote sites so that it replicated itself and each replication took on a divergent evolutionary path, the results of which could also be fed back to the central model to contribute to the gene pool. And third, by allowing access to the exhibition and the book via a conventional Web site so that the context could be understood and the stages in the development of the evolving model could be observed.

The exhibition installation and virtual visitors

For the exhibition installation three interlinked computers were in use. The central machine handled the evolving model and displayed a rendered visualisation of the developing cell structure and a representation of the landscape of the genetic search space. One computer handled communication with the outside world and received input from the environmental sensors in the exhibition space, input from gene switches for visitors to experiment with, output sound generated by the system and was directly connected to the Internet to receive and transmit genetic information. The third computer generated images of the emerging forms and provided an animation of the growth and development of the model.

Virtual visitors could view the current state of the model and receive an explanation, or they could participate by providing genetic or environmental information. For real enthusiasts, copies of the software were available for downloading. Feedback from remote copies of the software also affected the source model.

In the first two weeks after the launch of the model it evolved four family members based on the chromosomes received and those bred internally, each member achieving chromosomal stability in about 120 generations. Though it is impossible to predict the nature of the model, or its evolving internal logic, there seems to be a pattern emerging towards its selective and hence, evolutionary process.

With the assistance of Ellipsis publishers the virtual version of the exhibition was launched on the Internet in January 1995 (http://www.gold.ne/ellipsis/evolutionary /evolutionary.html). There are some successes and failures to record with this experiment. The central model convincingly demonstrated the principle of evolving a structure under the influence of both public participation and environmental information. But the rate of change was too slow to give any indication of how any individual was affecting it, and the feed back to the net was never properly implemented to show any development. Downloading the model to remote sites revealed all manner of technical problems which meant that biodiversified genetic material never found its way back to the central model. The Ellipsis site was labyrinthine which delighted many visitors but frustrated others who never found how to input genetic information. Overall the experiment attracted a great deal of comment, both on the net and in the press including a feature in Wired (Kunzru, 1995) and an article in Architectural Design (Frazer, 1995c). The Web site enjoyed a large number of visitors.

Vignette 6: Citizen co-operation in urban design: The Groningen Experiment

This section describes an experimental co-operative model for the city of Groningen in northern Holland. It then speculates on how such techniques could be broadened and applied to the possible global co-operative evolution of cities.

The Groningen context

Groningen enjoys a reputation for urban design and planning innovation and contributors over the last few years have included Rem Koolhaus, Will Alsop, Zaha Hadid, Bernard Tschumi, Henri Ciriani, John Hejduk, Daniel Libeskind, Paul Virilio, Philippe Starck, Coop Himmelbau, Allessandro Medini, Mecanoo etc. Groningen now have a development plan to the year 2005 and are starting to look beyond at urban strategies for the 21st Century. In this future context, I was asked in collaboration with colleagues and students from the Architectural Association in London, to demonstrate the potential for an intelligent, interactive, evolving, co-operative computer model of a sustainable urban environment which would enable the citizens of Groningen to interact and influence the development of their city.

Exploring new urban strategies

One of the key speakers in the "Opening the Envelope" series which formed the briefing for the project was Maarten Schmitt the Chief City Planner. His talk was crucial to the direction taken by the project described in this paper (Schmitt, 1995).

He said, "A very special atmosphere has been created in Groningen since the sixties revolutionary atmosphere. The intention has been to create a more meaningful and coherent society related to such ideals as the American Pueblo society, especially in reaction to previous failures in post war European cities.

The quantitative growth of the 60s in Groningen became an accumulation of private aspirations without any larger ambition and caused a social reaction. The social collective ambition grew out of this reaction, focusing on qualitative concerns. From this developed a larger idea or framework for cultural, economic and social elements of the city. This included reducing the role of the car, enabling coherent space for other activities combined with cleaning public space in order to give it back its public meaning. Discussion about alternatives for the worn out city elements, and the introduction of a pluriformity of uses and meanings into the centre became crucial to a dynamic view of the city and the need for change as a revitalisation agent. Reducing mobility and encouraging a diversity of service industries back into the inner city was a crucial achievement of this social democratic ambition.

Around 1980 the discussion on formal objectivity (creating symbols) in urban development was raised in professional circles, to develop the cultural identity of the city as a whole. The main spatial structure formed a fixed framework for continuously changing uses. These ideas were defined in the structure plan of 1987. These projects also explored a new type of public participation based upon the idea of planning by communication of which participation is an important part. This is initiated by a framework proposition for urban development which then involves wide public involvement and comment with the final responsibility held by the city council to assess and define the outcome.

The nature of the model

We produced a generative computer model which could mediate in scale, space and time. - In scale between the urban context and the fine grain of the housing typologies. - In space between the existing fabric of Groningen and specific dwelling units. - In time between the life style of the medieval core and the future desires of citizens of the next century.

An Evolutionary Model which explained the transition from the past to the present and projects trajectories for future possibilities. A "what if" model for exploring futures and evaluating them

More specifically we developed a model which simulated the historical development of Groningen in a dynamic and predictive manner. We searched in the local situation for local rules which would generate self determining emergent properties for the whole. We looked specifically at the way in which the implications of changing life styles and work patterns could be incorporated into the model. We developed a structure for the model which was strategically modular (in the sense that say a tree is) without being geometrically constrained to modularity. We embodied all ideas for the housing typologies and the site organisation including environmental influences.

The model was designed using the techniques which we had developed over the last few years (Graham, 1995, Graham, Frazer & Hull, 1993, Frazer, 1994). The structure of the model was new and specifically tailored to the scale and nature Groningen.

The operation of the model

Central to the Groningen model is the idea that the computer program inhabits an environment, enters it, reads it, understands its developmental rules and history, grasps its topography, latitude and climate, models its society and economy - and then starts to solicit suggestions and make proposals for possible features.

The model becomes an inhabitant. It maintains a discourse with other, human inhabitants and tries to understand and interpret their desires, aspirations, urges, expectations, and reactions to their existing environment and projected future environments. On the basis of this interaction with the actual inhabitants, the virtual Inhabitor patiently modifies its criteria for evolutionary development and selection, endlessly repeating the process of refining and modelling prototypical futures. As it does so, it occasionally produces experimental genetic mutations or amplifies variety.

The Inhabitor models the desires, aspirations, urges, expectations, reactions of the inhabitants to their environment and projected new environments.

The Inhabitor can inhabit at any level: cell, room, house, district, city, regions, continent, planet. It can inhabit past environments, present environments and possible re-inhabitation of past and present habitats, and from the interaction of citizens who provide feedback tendencies and selection criteria.

The core of the Inhabitor is the Evolver, an evolving genetic model in which the isospatial datastructure and genepool are controlled by genetic algorithms. The Evolver is a recursively self-similar program which employs the same strategies at each level of interaction. It provides starting configurations or seeds for genetic algorithms, which learn on the basis of feedback from specific sites. The criteria for genetic selection are determined by citizen interaction with the Enabler.

The Enabler has connections to an interactive map (input desire lines, etc.) and an active output model. This is the basis for dialogue between the virtual Inhabitor and the real inhabitants.

The Generators: A hierarchically self-similar datastructure models the environment at the regional, urban, district and site scales (part of a continuum of scales, from global down to cellular). The datastructure is strategically modular without being geometrically constrained to modularity. It can interact with other sites at the same level, or with other levels, either top down or bottom up. Using specific data (GIS), these levels are mapped to specific situations and respond to exogenous influences. In the case of Groningen, the demonstrations are at the level of the local topography, the city form, the Ooesterhamrick district and the Ciboga site. Generative modellers actively generate new possibilities from inputs the Evolver. In turn, feedback from the specific sites affects the selection processes in the Evolver.

The implementation of the Groningen prototype

The working prototype was demonstrated in Groningen and then in London in June 1996. It was subsequently exhibited at the Architectural Association in July (Frazer, 1996a). An interactive map with video input of modelling blocks provided an easy interface to the system. The demonstrations were very favourably received and many valuable comments were recorded. The intention now is to seek further funding for a robust demonstrator system which can be used to test the system with the inhabitants of Groningen. Holland is a cafe oriented society. The intention is to provide interactive systems in some of the many cafes of the city (Frazer, 1997).

To paraphrase Stafford Beer "The public is conceived as a system, a model of which is contained in the computer. The public supplies minimal information, which the computer then synthesises in the model. This amplifies variety as required to help the public and attenuates variety to help the manager - thereby meeting the requirement of the law of requisite variety for each of them".

Interaction with the Inhabitor is achieved via the Enabler which has connections to an interactive map (input desire lines etc) and an active output model.

We feel that this experiment went some way to realise, through the medium of modern digital technology, the preoccupation of Patrick Geddes that the ordinary citizen should have a vision and a comprehension of the possibilities of his own city. This experiment addresses the need for and value of "citizen participation" in town planning. It also demonstrates the need for a Civic Exhibition and a permanent centre for Civic Studies in every town - an "Outlook Tower". We are proposing that the cafes of Groningen should be the Outlook Towers of the future.

Vignette 7: Global co-operation in the Electronic Evolution of Cities: The Talking Cities Project

Towards the end of the project another possibility developed. One of the students involved in the project, Cristiano Ceccato, suggested that the experiment should be extended to networking globally such models of cities. The intention was that the different models should learn from each other producing a wealth of experience in different situations. This idea was also prototyped by networking a series of computers each representing a different city at different latitudes and with different economies. This made it possible to demonstrate dramatic difference in the solar envelope at different latitudes and the effect of different economies on growth patterns.

We referred to this as "talking cities" in deference to the "walking cities" of Ron Herron whose recent death had deeply shocked us all.

Now I have moved to Hong Kong there is added motivation to realise such a global network of cities co-operating with each other in their evolution. We aspire to create a virtual global city, a connectivity of urban models communicating and exchanging information and experience around the world.

Potential collaborators are most welcome.

References

1. Frazer, J.H. (Feb.1979). ‘Cedric Price’s Generator. Building Design.
2. Frazer, J.H., & Connor, J.M. (1979). A Conceptual Seeding Technique for Architectural Design. In: PArC79, proceedings of International Conference on the Application of Computers in Architectural Design, Berlin, Online Conferences with AMK, 425-434.
3. Frazer, J.H. (1982). Use of Simplified Three Dimensional Computer Input Devices to Encourage Public Participation in Design. In: Computer Aided Design 82, conference proceedings (Butterworth Scientific), 143-151.
4. Frazer, J.H. (1992) Datastructures for Rule-Based and Genetic Design. In: T. L. Kunii (ed.), Visual Computing - Integrating Computer Graphics with Computer Vision. Tokyo: Springer-Verlag. 731-44.
5. Frazer, J.H. (1994) The Genetic Language of Design in Textiles and New Technology. In: S. Braddock, & M. O'Mahony (eds.), 2010. London: Artemis. 77-79.
6. Frazer, J.H. (1995a). An Evolutionary Architecture. London: Architectural Association Publications.
7. Frazer, J.H. (1995b). An Evolutionary Architecture. London: Architectural Association. The generous support of the Arts Council of England is gratefully acknowledged for both the book and the exhibition.
8. Frazer, J.H. (1995c). Architectural Experiments in Cyberspace. Architectural Design, 78-79.
9. Frazer, J.H., Graham P.C., & Rastogi M. (April 1995). Biodiversity in Design via Internet. In: Proceedings of Conference Digital Creativity, Brighton, 97-106.
10. Frazer, J.H., Rastogi, M., & Graham, P. (1995). “The Interactivator“, Architectural Design, Architects in Cyberspace, 80-81.
11. Frazer, J.H. (1996a). "The Groningen Experiment", Projects Review. London: Architectural Association Publications. 108-111.
12. Frazer, J.H. (1996b). The Paradoxical Image of the Virtual World: Towards a New Theory of Spaces and Places. (in Japanese) Ten Plus One, 10 + 1, 6, 100-103.
13. Frazer, J.H., & Frazer, J.M. (1996). The Evolutionary Model of Design. In: Approaches to Computer Aided Architectural Composition, Technical University of Bialystok. 105-117.
14. Frazer, J.H. (April 1997). Action and Observation: The Groningen Experiment. Abstracts of papers for Problems of Action and Observation Conference. Amsterdam. 14-16.
15. Graham, P.C. (1995). Evolutionary and Rule-Based Techniques in Computer-Aided Design, Doctorate Thesis, University of Ulster.
16. Graham, P.C., Frazer, J.H., & Hull, M.C. (1993). The Application of Genetic Algorithms to Design Problems with Ill-defined or Conflicting Criteria. In: R. Glanville, & G. de Zeeuw (eds.), Proceedings of Conference on Values and (In)Variants. Amsterdam. 61-75.
17. Greig, J. (1988). Celebrating the Cerebral. Building Design, Supplement, May.
18. Kunzru, H., & Search, J. (1995). Architects of Change. Wired, July/Aug, 68-71.
19. McKean, J. (1989). Learning from Segal. Birkhäuser.
20. Pearman, H. (1985). Computer-Aided Living. Design, September.
21. Schmitt, M. (1995). Exploring New Urban Strategies. workshop in the Opening the Envelope series. Groningen.
22. Sudjic D. (1981). Birth of the Intelligent Building, Design, January.

The Timeless Way: Making Living Cooperative Buildings with Design Patterns

Lyn Pemberton and Richard N Griffiths

University of Brighton,
Faculty of Information Technology,
Watts Building, Lewes Rd., Brighton, UK
Email: lyn.pemberton@brighton.ac.uk
r.n.griffiths@brighton.ac.uk

Abstract. Interfaces to information systems, and the buildings in which such systems are embedded will typically be the result of the work of a large number of different disciplines, potentially ranging from ethnographers to architects. A common language and conceptual framework has the potential for greatly enhancing the effectiveness and ease of cross-disciplinary communication. In this paper we describe some aspects of the notion of design patterns developed by architect Christopher Alexander and colleagues in the 1970's. We briefly show how Alexander-style patterns can be used for analysis and design in some of the disciplines implicated in the creation of successful cooperative buildings — interface design, ergonomic design, functionality design and office design and suggest that pattern languages might be a way of bridging the communication gaps between professions to produce a shared vision of the cooperative building project.

Keywords. design patterns, guidelines, human-computer interface, ergonomics, interior design, software design, communication

1 Introduction

Interfaces to systems, and the buildings in which systems are embedded will typically be the result of the work of a large number of different disciplines. Systems analysts, knowledge engineers or even ethnographers may have been involved in discussing needs with sponsors, domain experts, managers and potential end-users. They will need to talk to software designers who will in turn communicate their ideas to programmers. In some cases the designers of the casing for the systems will need to consult furniture designers and interior designers, and these experts and others will in turn liaise with architects. Clearly it would make sense if, rather than each profession conceptualising the problem and the solution in its own way, they shared some terms and mental structures for communicating the design goals and constraints which apply in each area. Buildings need to be designed by people capable of speaking a common language.

We think the various processes involved in design can usefully be informed by the imaginative and thoughtful work on architectural and engineering design which took place from the sixties onwards in the US and Europe[1]. In particular, in the complex multidisciplinary domain of cooperative building design, we see a place for design patterns, originally introduced by architect Christopher Alexander and colleagues, in two books, A Timeless Way of Building (Alexander, 1979) and A Pattern Language (Alexander et al, 1977). Though developed in the domains of architecture, town planning and interior design, Alexander's thinking on design patterns has been applied very intensively over the last few years in one area of computer systems development, that is object-oriented design. There it has proved very powerful and fruitful (Gamma et al, 1995). This proof that the design pattern approach travels well has encouraged other initiatives in the software design area[2] and makes us optimistic that it should be a useful conceptual tool for the range of specialisms which would go to make up the design thinking for a co-operative building.

In this paper we first give a brief introduction to design patterns. We then give some examples of the patterns which can be uncovered at four levels: interface design, software functionality, ergonomic design and office design and conclude with some practical steps which would represent a way forward.

2 Background: What Are Design Patterns?

Patterns grew out of Alexander's disaffection with the quality of architecture in the 1960's, which he attributed in part to the misapplication of formal methods in architectural design. This had resulted in buildings which failed to fulfil the real needs of the people who lived and worked in them, which failed to adapt to local social and physical environments and which people simply did not like (cf. Lea, 1997). Alexander contrasts these modern failed building with the many successful, "living" buildings, created in other societies, buildings which for Alexander embodied "the quality without a name", a recognisable but indefinable quality which floats in the semantic space bordered by terms such as "alive", "whole", "comfortable", "free", "exact", "egoless" and "eternal". Patterns are conceptual tools for helping people design buildings which might themselves have that quality.

A pattern is the solution to a problem in a context. To put it less succinctly, in a context or a set of situations, a problem or clash of constraints will occur, which is amenable to resolution by a canonical design form or solution. The pattern encompasses all three elements: the situation, the problem of clashing constraints or forces,

---

[1]It is encouraging to see software design finally positioning itself as one design discipline among others and thus enabling itself to benefit from the work done by design thinkers such as Christopher Alexander, John Chris Jones, Nigel Cross, Bryan Lawson, Geoffrey Broadbent, Horst Rittel and Bruce Archer to name only some of the stars in the design firmament. For a good introduction see Cross 1984 and bibliography. For recent work in software design which takes a design research slant, see some of the contributions in Karat (1991) and particularly (Winograd 1997).

[2]In particular the Pattern Language workshop organised at CHI 97 (Erickson).

and the canonical solution. An example problem in a context, from Alexander, would occur where parents and children live in a house together (context), in which the parents would like their own space away from the children, but still want to be able to go easily to the children if, for instance, they are ill or anxious at night (problem). A standard solution would be to create a separate space for the parents, still within easy reach of the children's room. This is the pattern "Couple's Realm," number 136 among the 253 patterns presented in A Pattern Language. Like all the patterns it is connected both to larger patterns, which it completes, including, in this case, "house for a couple" and "intimacy gradient", and to smaller patterns which in turn complete it, in this case "low doors", "sitting circle", "light on two sides" and "marriage bed" among others.

At the highest level we find patterns such as "Independent regions", "Country towns" and "The distribution of towns", while at the other end of the scale are detailed patterns covering the need for a bench by a front door and for different sorts of chairs to be provided in a room. Together the linked patterns form a Pattern Language, a kind of informal grammar for buildings and spaces.

The solutions are not simply pre-formed parts of a building kit. A pattern is an abstraction from any specific examples: this is what gives patterns their generative power. They do not supply ready-made answers: people need to exercise their own creativity to implement a pattern. In addition, because they involve abstracting away from individual cases, patterns are hard to discover and may take a long time to describe adequately. (Alexander and colleagues spent over ten years refining A Pattern Language and Alexander commented that finding patterns was a hard as theoretical nuclear physics).

Alexander's own patterns are structured and formatted as follows (Alexander et al, 1977):

Title:	Which succinctly (and evocatively) captures the *solution* that the pattern offers.
Asterisks:	To mark the significance of the pattern, two asterisks marking a "true invariant", one marking a pattern which has made progress towards identifying such an invariant, but which needs further work, and no asterisks indicating confidence that an invariant has not been established, and that variations are to be expected.
Picture:	"... which shows an archetypal example of that pattern." This may be literal or impressionistic. A subsidiary function may be to help the reader remember and find the pattern subsequently.
Introduction:	Setting the context and linking to higher level patterns.
¤¤¤	To mark the beginning of the problem.
Headline:	(In bold type) summarising the essence of the problem.

Problem body: Describing the empirical background of the pattern, the evidence for its validity, range of variation of manifestation.

Solution: (In bold type) Describing the "... field of physical and social relationships which are required to solve the stated problem in the stated context." as a statement, in imperative form.

Diagram: Of the solution (For Alexander the solution should always be capable of a diagrammatic representation.)

¤¤¤ To mark the end of the main body of the pattern.

Connections To lower level patterns which are required to complete this pattern.

Pattern makers in other disciplines have adapted this layout as needed.

3 Patterns in Cooperative Building Design

We think patterns should provide a valuable conceptual tool in several areas of design implicated in building design, from representations of the findings of ethnographic studies of the workplace to desk and console design to the nitty gritty of object-oriented programming, where they already enjoyed a great success. At all these levels they could enable designers to benefit from the knowledge and experience of creators of successful systems, providing reusable templates adapted to fit the particular issues which the designer is addressing. Above all, patterns, because they are themselves alive and engaging, provide a means of communicating either between designers of similar artefacts, e.g. one architect or interior designer to another, or designers looking at reshaping the environment at quite different levels, e.g. furniture designer to interface designer, or ethnographer to architect.

Why? What do software systems have to do with buildings? Pattern languages seem to resonate with three sorts of rhetoric heard in the more user-aware parts of the software design community:

- many designers recognise that there is a measure of discontent amongst users about the systems designed "for" them, and this is, in part at least, to be laid at the feet of a rigid application of formalistic methods of analysis and design which shut out the user from all except the very earliest design discussions.

- intuitively, the idea of "liveness" in buildings, the quest for the quality without a name, has much in common with the intuition that the systems which genuinely enable users to work as they want are want are those which we can call "engaging" or "convivial" systems. These are terms, like Kay's (1990) and Tognazzini's (1993) remarks on the place of magic in the interface, which seem to bound a similar semantic space to the quality without a name in the sphere of software. Systems with this quality, like Goldilocks' porridge, are “just right”.

- much of Alexander’s approach is evocative of recent moves in the HCI community towards participative design and user centredness. Alexander goes further than mere participation, in fact. The whole of "A Pattern Language", for instance, is predicated on the assumption that the person using the patterns will not be the trained architect but the person who will be living or working in the building.

3.1 Why are design patterns relevant to interface design?

Interface design is particularly obvious as a domain that would lend itself to pattern approaches. Interface design has always been about metaphors, however loosely conceived: even a primitive command line interface was based on a metaphor of conversation. With the advent of the graphical interface these metaphors have become increasing spatial. The desktop metaphor is ubiquitous, in the Web (itself a spatial metaphor) terms such as home and site are commonplace, and it is now common to speak of information spaces and to design visualisations of data in 2-D and even 3-D spaces. The mapping between source and target terms in any metaphor is never complete and one-to-one: metaphors, in interface design as in language, will always break down sooner or later (cf. Lakoff and Johnson, 1980). However, again in interface design as in language, users seem to be able to handle this: if not they would feel less easy about desktops which contained not only folders but also objects rarely encountered on top of desks such as windows, menus and wastebaskets. People have little difficulty in associating modern interfaces with the sorts of objects and relationships which are the stuff of Alexander’s patterns.

3.1.1 Some Design Patterns for interface design

When searching to identify design patterns in interfaces, it is probably as well to remind ourselves that whereas the buildings which Alexander considered were the result of many hundreds of years of development, interfaces are at a relatively early stage. There are few universally acclaimed solutions and this may mean that it will be easier to identify problems than to describe the solutions which address them. In Alexander's terms, it may be that any patterns we do find will not deserve asterisks. However, in a pioneering spirit, below are just a few patterns which can be discerned in interface design. The first of these, which describes the need for the user to receive feedback when interacting with a system, is described in full, in Fig. 1, while the rest are left in outline "context, problem and solution" form. Figures in parentheses are references to other, fictional, patterns which would have to exist in a complete pattern language.

1 Interaction Feedback *

. . . . users working at data processing tasks on conventional workstations — DESKTOP METAPHOR (23), GRAPHICAL USER INTERFACE (67) — will need to be aware of the current mode of the system —ALWAYS INDICATE CURRENT MODE (42) — and must have an indication that their input has been accepted by the system.

¤¤¤

People need to know that the system has registered an interaction event, such as mouse click, mouse movement, arrow movement, keyboard press, etc.

Where an interaction event is only part of a sequence of commands to a system, or where no explicit user perceptible effect is achieved, people can become anxious that they have not been "heard" by the system, and may repeat the click or movement.

This anxiety can be relieved by giving some feedback — proportionate to the scale of the interaction event and its significance — to confirm to the user that the system has registered the event. Possibilities include, indenting a button, back-lighting a word, changing the shape of the cursor, making an audible click or beep.

For instance, the satisfying "zip' when a window is rolled up or down in the Mac System 7.1a interface, the simple clicking of the mouse button, the movement of the key when hit by the finger, the "ghost" of the folder as it is closed and "replaced" in its parent folder.

In some work environments, an audible feedback may cause annoyance, so it must be possible for the user to silence it.

Therefore: **Give visual feedback and allow the user to enable audio feedback for every interaction event.**

¤¤¤

If the computer action that has been initiated by the interaction event is going to take a significant amount of time to complete, then an indication if this should be given — SHOW COMPUTER IS THINKING (34) . . . .

Fig. 1. Pattern describing the need for the user to receive feedback when interacting with a system

An immediate reaction to the idea presented here may be that it simply replicates (in a rather long winded way) what has already been done in HCI design through the introduction of style guides such as the Macintosh Human Interface Guidelines (Apple, 1992) — which actually references Alexander's work, The Windows Interface: An Application Design Guide (Microsoft, 1987), NASA Human-Computer Interface Guidelines (Carlow, 1992), and *very* many others. However we claim that what is missing from these style guides, and is added in the pattern approach, is the explicit acknowledgement that whole *patterns* are being recorded. This implies that the meta-information surrounding the simple imperative instruction[3] normally found in guidelines is recorded — and must have been thought through. This means explicitly setting the context in a hierarchical structure of patterns, drawing attention to the *problem* that the pattern solves, conceiving of the solution to the problem as resolving conflicts in a field of interacting social and physical relationships, and considering and stating degrees of confidence in the invariance of the pattern. This makes patterns an altogether richer resource for the designer than lists of guidelines — more akin to the resources to be found in what we have called "craft wisdom" books, a good example of which is Cooper (1995) — but expressed in a canonical form.

Secondly, the use of patterns implies an emphasis on the *process* of developing and using guidelines, rather than on the product — a list of imperative directions. A good pattern will have been evolved out of the experience (both successes and failures) and observations of a number of designers. It is susceptible to further refinement in a way that seeks to approach the underlying invariant, rather than simply recording more cases.

Additionally, the use of a pattern *language* holds out the possibility of involving the occupants of co-operative buildings, or the users of software interfaces in the design and modification of these artefacts. That we have not been able to address this possibility here does not indicate our lack of enthusiasm for it.

The **Interaction Feedback** pattern is shown to lead into another pattern:

"Show Computer is Thinking" Pattern

Situation: operations can take a long time
Problem: people need to be warned when an operation is going to take a substantial amount of time, otherwise they may assume something has gone wrong. They are unwilling to sit and wait if the wait is to be fruitless, but on the other hand they do not want to confuse the system by reissuing commands unnecessarily.
A solution: give special feedback for lengthy operations. Examples would include changing the cursor to a watch or egg timer, showing a timeline, filling a time-bar and so on.

This could lead into the next pattern.

"Just another 30 seconds" Pattern

Situation: operations can take a *very* long time.
Problem: sometimes people need to know what proportion of a task has been carried out, otherwise they may stop the operation just when it is about to end, or they may wait around by the screen unnecessarily when they might as well have gone for a cup of tea.

[3] For instance, "Do not use abstract or humorous designs for icons." Carlow 2.1.4

A solution: use a measuring bar or percentage or text representation to tell user how much more work there is to do. Examples would include the mechanism on many Web browsers showing that, say, 45% of a site has been downloaded; alternatively, the "copy" operation in Apple Mac desktop tells the user how many files are left to be copied both in textual and graphical format.

3.2 Patterns in functional design

As in interface design, the design of the *functionality* of a piece of software lends itself to description in terms of patterns. This should not be a surprise. Alexander's patterns are intended to create buildings which allow users to live as they want: pattern-like thinking for software functionality design should similarly aim to build systems which incorporate just those functions which help a user to do what s/he wants.

3.2.1 Some Patterns

At its simplest, a functional pattern would be little more than an element of a requirements specification document together with a rationale from systems analysis or a workplace study, as in the first two examples.

"Provide Mail Merge" Pattern

Situation: people producing large numbers of letters on a word processor
Problem: people want to send out personalised letters to lots of different recipients without typing in the individual names
A Solution: provide a mail merge facility, allowing personal details from a database to be integrated into a standard letter.

"Provide Multiple Filing Systems" Pattern

Situation: in paper systems, people often have documents that need to be referenced in two places or under two or more headings. In real life offices people work round this either by creating a copy of the document and filing one under each heading, or putting a referring note in one of the locations.
Problem: this is a problem in the paper world as it involves long hours by the photocopier or messy bits of paper which have a tendency to get lost.
A solution: the same functionality can be provided in a lightweight way via software by using a "duplicate" or better a "create a link" command in an operating system.

"Think Twice" Pattern

Situation: the user may accidentally carry out an action which has serious consequences, such as deleting a file, erasing a disc and so on.
Problem: how to avoid disastrous errors while maintain fluidity in the interface.

A solution: if the consequences of a command can be grave and/or are irreversible, ask the user to confirm the command, but make "continue" or "OK" the default option.

A follow-on pattern might suggest that in the case of extremely risky operations, the default option at this point should be the more cautious one.
Examples: in the Macintosh interface, the "Empty Wastebasket" command displays a dialogue box containing the number of items in the waste bin, together with their size and gives a choice of "cancel" or "OK" with OK, the *less* cautious option as the default. However, the "Erase disk" command brings up a dialogue box containing the name, location and type of disc and gives a choice of "cancel" or "erase," with "cancel", the *more* cautious option, as the default.

3.3 Relevance in ergonomic design

When we move to the level of the physical artefact in which the software is embedded, the pattern language structure can be used to point out general contextualised problems and general solutions which can be implemented to fit specific situations.

3.3.1 Some Patterns in Ergonomic Design

"Make a Computer that looks like a Filofax" pattern

Situation: business people want to carry their computers around with them.
Problem: business people tend to be relatively mobile, so heavy weights are impractical. They also tend to carry briefcases and paper-based objects such as reports, diaries and personal organisers.
A Solution: create a casing for the computer which lightweight, as handy as a Filofax and which business people can carry in the briefcase which is part of their "uniform".

"Make a computer like a pet mouse" pattern

Situation: a toy firm has developed an idea for a computer-based pet.
Problem: an electronic toy for children, like the portable computer, also needs to be portable. However, children tend not to carry briefcases (outside school, that is). Some have pockets, others not.
A Solution: build them something palm-sized and highly portable, either in a pocket, like a pet mouse, or on a cord around the neck

"Make a casing a gorilla can't destroy" pattern

Situation: a research project in animal understanding, which studied the abilities of a specific gorilla, Koko by name, in manipulating the American Sign Language.

Problem: the problem was that the computer had to be a Mac with touch-screen for functional reasons, but had to be able to withstand the attentions of the gorilla which included flinging it against a wall and inserting bananas though its vents.
Solution: a special housing in tough, gorilla-proof metal, described in more detail in Clark *et al.* (1990). This is perhaps an example of a pattern of the future. At the moment a solution has been found to a specific problem, but it is not hard to imagine how both problem and solution could be generalised. Casings for other difficult situations might use the same ideas in this pattern.

3.4 Patterns in the built environment

At yet another level we encounter problems or contexts in the physical world, which need a physical world solution but one which has a software element to it. Here we could imagine experimenting with Alexander's patterns unchanged as they should apply directly. In particular Alexander's patterns 146 - 252 on work situations, covering flexible office space, communal eating arrangements, small work groups, reception areas, waiting areas, small meeting rooms and half-private offices will have direct applicability to cooperative buildings in enabling people to meet and also to withdraw into privacy as they wish.

3.4.1 Some patterns

Some patterns can be discerned at the level of furniture and consoles.

"Attach a Document Holder" Pattern

Situation: the user needs to be able to refer to a document while using the screen.
Problem: there often isn't enough room on the desktop (which is taken up by the computer) and anyway looking down at the document on the desktop would mean constantly shifting one's focus of attention with all the attendant disorientation problems that this implies.
Solution: attach a document holder to the side of the terminal

Others treat the wider workspace:

"Sociable Terminals" Pattern

Situation: a current workplace design, e.g. in a control room of some sort, allows co-workers to consult each other's work. For instance, colleagues glance at each other's screens when walking to the coffee machine and often pick up problems as they do so.
Problem: there are moves to introduce a system of small cubicles for workers. This would mean that the extra check afforded by glancing at a colleague's screen was no longer available, possibly lowering safety standards.

Solution: design the new layout perhaps as a horseshoe, making sure screens are big and readable and of common design.

This pattern might be linked to the following pattern, which refers to the need for co-workers to be in auditory rather than visual contact.

"Let people overhear" pattern

Situation: a current workplace design, e.g. in a control room of some sort, allows co-workers to overhear each other's interactions, including telephone conversations, and sometimes to act on what they overhear. Sometimes this is trivial: the person on the telephone says "I'll just find a pen…" and person B hands one to them. At other times a rapid response is vital, as when person B picks up from person A's urgent tone on the telephone that an accident has occurred. This often means a quicker response to critical incidents than if the person on the telephone had to explicitly relay the information to his/her colleague.
Problem: as in the preceding pattern, there are moves to introduce a system of small cubicles for workers. This would mean that this benign overhearing was no longer possible.
Solution: Rethink the design and don't put people in boxes or out of eye contact or in completely soundproof headphones.

The current trend to carry out quasi-ethnographic studies of workplaces such as control rooms as a prelude to the redesign of collaborative software has led to the problem of finding a language in which the social scientists carrying out the study can structure their results for clients and designers. As Erickson (1997) has suggested, patterns may provide just such a form, as these examples briefly demonstrate.

4 Concluding Questions and Exhortation

Integrating systems into environments involves considering the links between many disparate levels of analysis: the relation between what the user wants to do and the functionality of the system, the design of the screen within the input/output device, the physical relation or interface between user and input/output device, and the placing of the device and the user(s) in the wider physical context. While these have traditionally been treated separately, Alexander's approach suggests that integration is not only possible but necessary.

Design Patterns give us a set of terms, concepts and values which have resonances at every level of the design of both software, hardware and the built environment. We have hardly scratched the surface in this paper, but we feel the approach is promising and that it would be would be foolish not to explore further. At the moment we find ourselves in the position of simply feeling that design patterns *should* be of use to designers. Their analytical and descriptive power is impressive, but what we really need are aids to *synthesis* not to *analysis*. One way to find out whether they are really useful is, as Lea (1997) suggests, for people to stop writing *about* design patterns and to get down to the business of identifying and describing them in a public forum so that they can be smoothed and polished by the comments of peers and can eventually form part of the discourse of co-operative building design.

References

1. Alexander, C., Ishikawa, S. & Silverstein, M. (1977). *A Pattern language.* Oxford, Oxford University Press.
2. Alexander, C. (1979). *The Timeless Way of Building.* Oxford, Oxford University Press.
3. Apple Computer, Inc. (1992). Macintosh Human Interface Guidelines, Addison-Wesley Publishing Co.
4. Carlow International, Inc. (1992). Human-Computer Interface Guidelines, NASA, Goddard Space Flight Centre, http://groucho.gsfc.nasa.gov:80/Code_520/Code_522/ Documents/HCI_Guidelines/ viewed Dec 18 1997.
5. Clark, M., Ferrara, T., Jones, D., Marion, A., Rose, K. & Yaeger, L. (1990) Koko's Mac 11. In: Laurel, B. (Ed.), *The Art of Human Computer Interface Design.* Addison Wesley. 95-102.
6. Cooper, A. (1995). About Face: The Essentials of User Interface Design. IDG Books.
7. Cross, N. (1984). *Developments in Design Methodology.* Chichester, John Wiley.
8. Cross, N., Christiaans, H., & Dorst, K., (Ed.) (1996). *Analysing Design Activity.* Chichester, John Wiley.
9. Erickson, T. *Report on Design Patterns Workshop CHI '97.* http://www.pliant.org/personal/Tom_Erickson/, viewed Nov 1,1997.
10. Gamma, E., Helm, R., Johnson, R., & Vlissides, J. (1995). *Design Patterns.* Addison-Wesley.
11. Jones, J. C. (1970). *Design Methods.* New York, Wiley.
12. Kay, A. (1990). User Interface: A Personal View. In: Laurel, B. (Ed.), *The Art of Human Computer Interface Design,* Addison Wesley. 191-207.
13. Lakoff, G. & Johnson, M. (1980). *Metaphors We Live By.* Chicago University Press.
14. Lawson, B. (1980). *How Designers Think.* London, Architectural Press.
15. Lea, D. (1997). *Christopher Alexander: An Introduction for Object-Oriented Designers.* http://g.oswego.edu/dl/ca/ca/ca.html, viewed Nov 6, 1997
16. Microsoft Corporation (1987). The Windows Interface: An Application Design Guide, Microsoft Corporation
17. Tognazzini, B. (1993). Principles, Techniques and Ethics of Stage Magic and their Application to Human Interface Design. In: *Proceedings of CHI '93.* 335-362.

Sustainability of New Work Practises and Building Concepts

Niklaus Kohler

Institut für Industrielle Bauproduktion - ifib Universität Karlsruhe
Englerstrasse 7, D-75128 Karlsruhe
Email: niklaus@ifib.uni-karlsruhe.de

Abstract. New forms of communication and co-operation do not have the same environmental impact pattern as current forms of work. Environmental impacts are produced by work technologies (mainly communication technologies), buildings (construction, maintenance, operation and destruction) and transport (induced by work relations and housing). The thesis that new information technologies reduce transport and building energy consumption has not been verified in practice until now. The contribution discusses the interrelation between different impacts, gives quantitative data of environmental impact based on the combination of existing life cycle analysis and tries to estimate possible future developments. The question of the necessity of new buildings and the possible development of virtual buildings is discussed in relation with sustainable development.

Keywords. buildings, work practise, life cycle assessment, sustainability

1 Introduction

New work practices such as telework, new technologies like the internet and new forms of buildings like „intelligent“ or „cooperative“ buildings are presented as having large advantages from an environmental point of view by inducing less motorised traffic, reduced energy consumption, and the use of less resources through the dematerialisation of their components. These advantages are often summed up as part of a „sustainable“ development. The contribution will start out by giving a working definition of the different aspects of sustainability and life cycle assessment (LCA). The possibility of life cycle assessment of new work practises, communication technologies and buildings are discussed; existing quantitative attempts are situated. The necessity of new building types for new work practises is analysed and different building concepts are discussed. Finally, the contribution tries to answer the question on how new work practices and new technologies influence operation and management of individual buildings and the building stock in a long term perspective.

2 Definition of Sustainability

The German parliamentary Enquete-Commission for the „Schutz des Menschen und der Umwelt“ gives the following definition of sustainable management: „The rate of decrease of renewable resources should not be larger than their rate of regeneration. Non-renewable resources should only be used to the extent that an equivalent replacement in form of new renewable resources or a higher efficiency of both renewable and non-renewable resources can be granted. The environmental impact through emissions and waste should be adapted to the reception capacity of the environmental compartments.“ (Enquete Kommission „Schutz des Menschen und der Umwelt“ des Deutschen Bundestages, 1997). In general a sustainable development should assure social, economical and environmental (ecological) benefits.

3 Assessment of Sustainability

In general, there are different methods to assess the three aspects of sustainable development within the framework of a technology assessment. There are very few attempts at an overall assessment of new communication technologies because of their complexity and their multiple material interrelations. We will concentrate in this contribution on the assessment of the environmental or ecological sustainability. The most common assessment method is Life Cycle Assessment (LCA). In order to determine the interaction between a product, a service or a technology and the environment (Odum, 1983), it is necessary to understand their environmental aspects, generally through the mass and energy flows induced throughout the product life cycle. According to Heijungs et al. (1992) and Consoli et al. (1993) there are 4 steps in an LCA.

- Objectives: system limits and functional units
- Inventory: mass input and output, including upstream and downstream process
- Classification: association of inputs (causes) with effects on the environment
- Evaluation: overall evaluation by aggregation of different effects

The establishment of consistent system limits is a first problem. Inside the modular approach which has been developed in the LCA community there is the possibility to link a specific domain of LCA to upstream and downstream process chains through common system limits. This method works well in the field of energy, transport, material and consumers products as well as with buildings. It is, however, difficult to determine the system limits of complex systems like the communication systems. Another difficult problem when applying LCA to complex situations is the definition of a common reference, a functional unit. Mass flows, impacts and effects can be related to a person, a workplace, a work unit, a technological unit, a building unit etc. Conventional office work can be described by a work hour of a person at a certain site using a certain technology. In the case of telework there are two or even more work sites, several types of equipment and the transport between the workplaces has to be taken into account in terms of time and distance. For each phase there has to be a specific LCA.

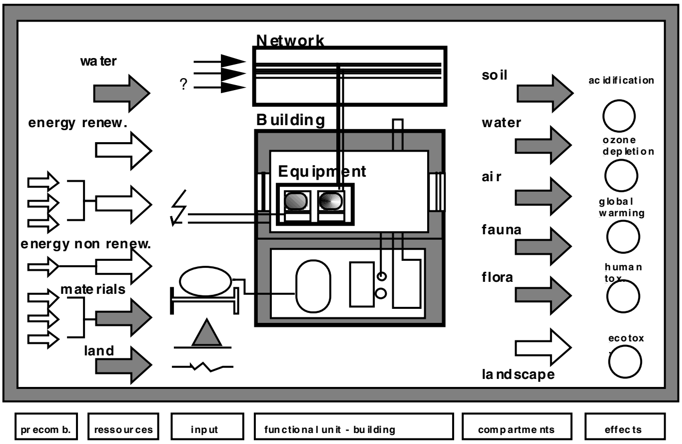


Fig. 1. System limits (Kohler, 1998) in an LCA of buildings and new communication technologies

4 Assessment of Work Practices, Communication Technologies and Buildings

4.1 Form of work

Current office work is considered as the reference, with one workplace linked to a network which is outside the system limits. The case of telework has been studied (ÖKOINSTITUT e.V., 1997). The results show that the difference in primary energy consumption per work place depends essentially on the resulting amount of individual transport. For the analysed real case the balance was negative for telework. In an optimised solution with little individual transportation, optimal use of equipment and energy efficient hardware, the telework had a slightly positive balance.

Distributed work practices and virtual enterprises allow to improve the communication within a team and to overcome the loss of time due to individual transport through synchronic and asynchronic collaboration over networks. The economic savings of teleconferences are quite evident and the reduction of the environmental impacts should be even larger than the economic savings (actual transportation costs do not take sufficiently into account environmental impacts). However, there are no overall studies of the effects of distributed work practice. The resulting rise in productivity can also reduce the number of work places. Although the unemployed persons are no longer inside the system limits, they continue to create environmental impacts through other activities.

4.2 Information and communication technologies

There are two parts which are strongly linked but which cannot be analysed in the same way. The communication networks are very difficult to analyse as process chains because of their complexity and because of the fact that the same network is often used for different types of existing and future applications. In some cases it is possible to estimate the environmental impact of complex systems through a macro-economic input/output analysis coupled to emission coefficients and resource consumption. The German macroeconomic input/output matrix (ITAS, 1997) is not detailed enough to isolate the economic activities for the production, repair and operation of large communication networks. Furthermore there are large international interdependencies.

Personal computers and other distributed input/output devices have been analysed and there are several LCA for personal computers (Grote, 1994; MCC, 1993; Soldera, 1995). The main findings are:

– the production of the hardware has a larger impact than its operation
– the mass input is much higher than the mass of the components
– the waste is composed of a large number of often not identified materials
– the screens based on cathodic tube technology have large production and operational energy needs.

4.3 Building construction and operation

Building LCA is certainly the most well developed. (Kohler *et al.*, 1994; Kohler, 1995, 1998). The environmental assessment is realised by a modular combination of upstream and downstream process analyses. All energy and mass flows are are derived from usual quantity surveying and building construction process data. The main problem lies in the assumptions concerning the very long life cycle. Basic data on all types of industrial process can be found in (Frischknecht *et al.,* 1995; Fritsche, Rausch & Simon, 1989].

Over an assumed life time of 80 to 100 years, most effect-oriented environmental impact factors show a relation (impacts through building and refurbishment versus impacts through operation) of approx. 1:6 for buildings with low energy efficiency and up to 1:1 for buildings with very high energy efficiency. The relation is somewhat different for human toxic and ecotoxic indicators where the impacts through building and refurbishment are more important. The situation of a building in relation to public transport, the distance to the the centre and to residences, and the type of transport used can make a large difference in environmental impacts.

As an illustration, the overall (primary) energy consumption for different combinations of building types, work equipment and amount of generated transport has been estimated. The basic data from (IFIB-HAB, Weimar-ETHZ, ESU, 1995; Kohler *et al.*, 1994; Kohler, 1998) have been used. Although a large database has been used for the basic process, the results are partial and the accuracy can be estimated to be +/- 20%. The primary energy has been chosen as an indicator for environmental impact because of the availability of data for all the considered processes. It is, however, not the only indicator. It correlates rather well with global warming effects but rather badly with acidification and not at all with environmental or human toxicity.

Building characteristics								
Building type	highly equip.	highly equip.	highly equip.	highly equip.	aver. equip.	aver. equip.	Best techn.	exist.
Building state	new	new	new	new	new	new	new	refurb.
Build.energ.efficienc.	low	aver.	high	low	high	high	very h	high
Work equip. efficien.	low	low	aver.	low	high	high	very h	very h
Use characteristics								
Surface p.person [m2]	20	20	20	20	20	20	20	20
Building life time [y]	30	100	100	30	100	100	100	100
Refurbishment [-]		2	2		2	2	2	2
Equipm.life time [y]	3	3	5	3	6	6	8	8
Transp. distance [km]	50	50	30	10	30	10	10	10
Public transport [%]	10	10	10	70	10	70	70	90
Primary energy consumption [kWh] per work place (20 m2) per year								
Build.construction	3467	2800	2800	3667	1640	1640	1380	960
Building operation	10760	6596	4606	10760	4606	4606	2432	3298
IT equip.&operation	3050	3050	1490	3050	1157	1157	725	725
Transport	13233	13233	7940	1359	7940	1359	1359	930
Total [kWh/y]	**30509**	**25679**	**16836**	**18836**	**15342**	**8762**	**5896**	**5913**
Relation [%]	100	84	55	62	50	29	19	19

Fig. 2. Primary energy consumption for different solutions

Certain assumptions have been made about the type of buildings. The so called highly equipped buildings correspond to buildings with moveable partitions suspended ceilings and floors and generalised HVAC equipment. The operation energy needs (heat and electricity) even for efficient ventilation, heating, cooling and lighting equipment are very high. The energy parts for construction, refurbishment and maintenance are high because of the particular materials and components used in this type of building. Transport plays a very important part in all solutions with large part of individual transportation. For the work equipment the data from LCA for PCs been adapted. The number of years of use of the equipment is quite important. Through upgrading the equipment can be used much longer. Good design allows a high degree of reutilisation on a high level at the end of the life time for all components. This effect has not been taken into account in the calculation.

As an alternative to highly equipped buildings, very simple buildings with sophisticated energy conservation and passive solar design, little technical building equipment and long lasting, low impact materials have been analysed. They are to be compared to the case of very efficient refurbishment. In all these cases the „intelligence„ lies in the design and operation process and not in the control equipment. If they are well designed, the adaptability of such buildings to new work practises and new communication technologies is equivalent to the highly equipped buildings.

5 What Kind of Buildings do we Need for New Work Practises and New Communication Techniques?

The statement that „current work spaces are not prepared for nor oriented towards the integration of IT infrastructure supporting work processes with the infrastructure for managing and operating buildings“ should be discussed. If in the beginning of the application of computers 20 years ago, computers needed very particular climatic conditions, developed large amounts of process heat, and needed special air-conditioned rooms, this is not true anymore for current IT and will be even less true for coming applications. It means that there is no need for complicated HVAC equipment if buildings are designed with the available design tools and run in a efficient manner (at least in central Europe). The space for networks has also been dramatically reduced. New developments allow to transport more and more information through TV cable and even through the electrical current distribution networks. As to the spatial capacity, all buildings with sufficient ceiling heights and which are not too deep can be adapted and equipped with all kinds of electronic input/output devices. This is particularly true for older industrial and warehouse type buildings. The refurbishment of large parts of recently built office buildings will allow the correction of at least some of the design and construction errors and equip these buildings with new networks. The development of always smaller, more decentralised and more autonomous IT allows new forms of work and of communication to adapt to a large portion of existing buildings. The argument that existing buildings are not capable of receiving IT infrastructure and new work practise and that there is therefore a need for new buildings, is probably no longer correct.

6 Buildings in a Long Term Perspective

The studies of the evolution of the German (ITAS, IFIB, IWU, Uni Dortmund & Fachhochschule Kiel, 1996) and probably most other European buildings stocks show the following tendencies:

- new building activities (above all of office buildings) are continually decreasing
- there are many old empty buildings (factories and warehouses)

– there is a growing amount of empty new highly equipped office buildings resulting from building overproduction and the effects of company reengineering (downsizing, outsourcing etc.)
– there is a problem of financial allocation between new construction, refurbishment and maintenance
– the mass flows (input) induced by building activities are 4 to 10 times higher than the waste mass flows (output). There is growing concern over the use of resources (materials, energy, land) and the resulting environmental impacts
– there is a growing risk of contamination of the whole building stock by undesired materials.
– there is a growing awareness of the risks of poor indoor environment quality (building illness through bad HVAC equipment, emissions from building materials, electrosmog from electronic equipment etc.)

The simulation of the evolution of building activities, mass flows, energy flows, land use and emissions show that a sustainable development of the building stock needs a dramatic reduction in the operational energy used, the replacement of new building and material production through longer use and the recycling of buildings and components at a high level. The reduction of special waste (which includes electronic waste) through better design of buildings and equipment is also a general issue.

At the same time, the demand for spaces for service activities and for innovative small industrial, service and R&D firms show the following tendencies:

– a rapid availability of space with good IT connections
– the possibility to reduce or increase space in short intervals
– low rent and operation costs
– the possibility to install rapidly IT technologies
– renting instead of building or buying (new construction is too slow, too rigid, too expensive or too capital intensive)

These demands are more and more taken into account by firms specialised in rapid refurbishment and transformation of existing, often empty buildings. As new owners, these firms have a specific interest in managing the buildings in a flexible long term perspective. They develop their own adapted and efficient FM tools independent of the actual user. Large firms have a tendency to sell their own building stock.

A similar development can be observed in the tendency towards the leasing of office equipment (photocopy machines etc.). One of the largest firms in this field continues to use the main components of machines and replaces only the obsolete parts. This strategy is economically and ecologically justified.

The overall strategy of sustainable development in the built environment, taking into account economic, social and ecological aspects is based on the following hierarchy:

– maintain and improve the existing urban and regional environment
– manage the building stock as the largest financial, physical and cultural capital of industrial societies in a long term perspective. This means that the building stock becomes the basic resource (Hassler, 1996).

– develop techniques to maintain, refurbish and adapt the existing buildings to new requirements as well as adapt new techniques to fit the existing buildings.
– for new buildings (replacement of demolished buildings) create long term adaptable structures.

It has been proven that short term adaptations of buildings to rapidly changing technical and social needs are inefficient in a long term perspective. There is a clear strategic difference between the short term management of buildings (use) and the long term (intergeneration) management of building stocks and urban contexts. The architectural efforts should therefore be concentrated on the imagination of a new social and cultural spatial environment which would accompany and improve new forms of work and communication instead of trying to adapt objects with life times of decades to IT techniques which change every three years.

7 Real Buildings and Virtual Buildings

The most promising aspect of the discussion about new work practises and new communication techniques resides certainly in the development of new conceptual tools like virtual worlds, virtual buildings, information building etc. There should be no confusion between the long term management of the real physical environment and the management of virtual worlds. Most attempts to qualify and differentiate buildings in a special way (like „intelligent“ buildings) neglect the extremely complex nature of real buildings which can not separated from their cultural and historic significance. Buildings in this sense are non-renewable resources. Simplistic technical concepts might in their restrictive way even lead to technically incorrect conclusions, because they underestimate the extremely rapid development of IT. The potential of new simulation methods to improve the energy and environmental design methods as well as the long term management of building stocks will probably play an important role.

The integration of new work concepts and communication technologies with building design and management is probably solved through the use of the building metaphor in many IT applications. Research in this field could improve considerably the domination of complexity arising from the modelling of large production and communication processes. The use of buildings in virtual worlds could coexist very well with the long term „sustainable“ use of real buildings as a complex social and cultural environment. There is no need to adapt existing buildings to virtual worlds.

References

1. Enquete Kommission „Schutz des Menschen und der Umwelt“ des Deutschen Bundestages (1997). *Konzept Nachhaltigkeit*. Deutscher Bundestag.
2. ITAS, IFIB, IWU, Uni Dortmund & Fachhochschule Kiel (1996). *Stoffströme und Kosten im Bereich Bauen und Wohnen.* Studie im Auftrag der Enquete Kommission zum Schutz von Mensch und Umwelt des deutschen Bundestages, Karlsruhe.

3. Frischknecht, R. et al. (1995). *ÖKOINVENTARE für Energiesysteme*. ETHZ/ESU, Bern.
4. Fritsche, U., Rausch, L., & Simon, K.-H. (1989). Umweltwirkungsanalyse für Energiesysteme: Gesamt-Emissions-Modell Integrierter Systeme (GEMIS), Darmstadt-Kassel.
5. Grote, A. (1994). Grüne Rechnung. Das Produkt Computer in der Ökobilanz.. In: c't 12, 1994, p. 92.
6. Hassler, U. (Ed.) (1996). *Das Denkmal als Altlast? Auf dem Weg in die Reparaturgesellschaft?,* Universität Dortmund 1995, ICOMOS Publication Heft XXI,1996.
7. Heijungs, R. et al. (1992). *Environmental life cycle assessment of products; Guide and Backgrounds.* National Reuse of Waste Research Programme, CML, Leiden
8. IFIB-HAB, Weimar-ETHZ, ESU (1995). *Ökoinventare von Baustoffen*. Karlsruhe.
9. ITAS - Institut für Technikfolgenabschätzung (1997). *Input-Outputanalyse und Emitentenstruktur*. In: TA Nachrichten 3, (4), Nov. 1997, p.117.
10. Kohler, N. et al. (1994). *Energie und Stoffbilanzen von Gebäuden während ihrer Lebensdauer*. Schlussbericht Forschungsprojekt BEW, Universität Karlsruhe.
11. Kohler, N. (1995). *Life cycle models of buildings.* In: EuropIA'95, 5th. International Conference on the Application of Artificial Intelligence to Architecture and Civil Engineering. Hermes, Paris.
12. Kohler, N. (1998). *Lebenszyklusbezogene Bewertung von Gebäuden - Methoden und Vergleiche*. DAM Deutsches Architekturmuseum. Frankfurt (to be published).
13. MCC - Microelectronics and Computer Technology Corporation (1993). Environmental Consciousness: A strategic Competitiveness Issue for the Electronics and Computer Industry.
14. Odum, H.T. (1983). *System Ecology*. New York.
15. ÖKOINSTITUT e.V. (1997). Umweltschutz im Cyberspace. Zur Rolle der Telekommunikation für eine nachhaltige Entwicklung. Freiburg.
16. Consoli, J. et al. (1993). Guidelines for Life Cycle Assessment: A Code of Practice. SETAC-Europe Bruxelles.
17. Soldera, M. (1995). Öko-Computer. Vergleich eines Öko PC mit einem herkömmlichen PC anhand einer Lebenszyklusbilanz. Gebensdorf (CH).

Cooperative Buildings
— The Case of office VISION

Ivar Moltke & Hans H. K. Andersen

DTI – Danish Technological Institute
Gregersensvej, P.O. Box 141, DK-2630 Taastrup, Denmark
Email: [ivar.moltke, hans.h.andersen]@dti.dk

Abstract. The paper discusses the research and developmental background for initiating a holistic "Cooperative Building" project named office VISION. The influence of the increasing global competition on organisational practices, information technological advances, research on cooperative work and its support and advances in energy and ecological technologies are discussed. The case of office VISION is presented. Office VISION is both a building, the framework for innovative office functionality and a complete consulting scheme for the office of the future. Within the office VISION project, we have initiated the development of 4 main themes: Sustainable working methods, democratic organisations, a healthy indoor environment and liberating cooperative technologies and new ways of organising work. Office VISION will be build in June 2000.

Keywords. cooperative buildings, sustainability, democratic organisations, healthy indoor environment, CSCW, evacuated glazing

1 The Vision

We have a dream in common about how the world should be. The Garden of Eden, peace, love, trust, cooperation, fertility, nature. This dream is shared by religions and human beings all over the world and it is closer to reality on a Polynesian island, than is our harsher climate in Scandinavia.

The office VISION project is holistic in nature. Cooperation with people from all over the world, with all groups in society, and within the office. We emphasize the integrated experiment with organisational practice, IT-tools for cooperation, entrepreneurial culture and trust. Even though the lion cannot pasture with the sheep, there has to be enough space for people to use their different talents for our common good.

Ecology, means relations between the organism (the human being) and its surroundings. An ecological building is therefore not just an ordinary construction with less poison in it. The garden is a beautiful example of, and a strong metaphor for, the symbiosis between human beings and their surroundings. Ecological culture.

The aim is to develop an attractive alternative to a normal building and normal work conditions. We aim at developing technology that makes this alternative financially attractive, when the cost development is paid, and defects and faults are corrected. Therefore we build office VISION knowing that it is a giant challenge to make great ambitions become reality. We have tried it before with villaVISION - a high technology house of the future.

There are a number of reasons why we think it is a good idea to design and construct the office VISION from a holistic point of view. One of our primary aims is that human biological, social and psychological needs should be met most **directly** aiming at minimum resource- and environmental strain.

The need for cooperation between different disciplines in designing a cooperative building like office VISION emerges in the recognition of difficulties in handling the complex interplay between dynamic developments within a huge and differentiated pool of knowledge. For example, the influence of the global competition on organisational practices, information technological advances, research on cooperative work and its support and advances in energy, and ecological technologies. In this first section of the paper we will take a short look on the first three examples, while we shortly will return to the last example in our presentation of the office VISION case.

2 Motivation and Approach

Given the current situation of global competition there is a need for improved coordination within and between organizations, i.e., commercial enterprises engage in more and more complex organisational control and coordination structures in order to improve effectiveness of production. Also tendencies within manufacturing organizations point to a shift toward the formation of more flexible work organizations, e.g., just-in-time principles, which mean reduction in stock inventories; company wide quality control, with total recall of manufacturing processes from design to sales and services; concurrent engineering, which means many simultaneous engineering activities; customer oriented manufacturing, e.g., increasing number of product variants. In addition there is a shift from the view of organizations as monolithic 'top-down' governed rational entities to a view encompassing horizontal coordination and communication.

We have also seen technological advances, i.e., the advent of low-cost and powerful personal computers and the introduction of Local Area Networks (LAN), Wide Area Networks (WAN). The Internet and "intranets" makes it possible to workers to share resources and communicate through the network. But in many senses the networked PC and the computer systems and –applications are based on thinking stemming from the industrial time area. If you step in to an office of today you will most likely se people placed in front of their PC much like in ancient typist rooms and much like the turner in front of his lathe. We must find other solutions if we wish to take the idea of an information society seriously. The Internet is one small step ahead, but information technological solutions can not stand alone. A holistic view on work, technology, organizations, environment, architecture etc. must be called upon. We see the area of "Cooperative Buildings" as a fruitful step towards creating holistic solutions.

The research field Computer Supported Cooperative Work (CSCW) is closely related to that of "Cooperative Buildings." CSCW is characterized by research related to organisational aspects related to the introduction of CSCW-applications in work settings, research into CSCW architectures, the role of ethnographic methods in CSCW systems design, the development of CSCW design methodologies, evaluation of CSCW-applications in work settings, the development of CSCW multimedia systems (including virtual reality systems) in supporting asynchronous and synchronous collaboration, and discursive topics related to the development of a conceptual framework for CSCW. Contribution has come from a wide range of different research disciplines, e.g., computer science, human computer interaction, participatory design, ethnomethodology, cognitive and social psychology, organization theory, linguistics, etc. There has not been much focus on how the physical settings the (perhaps except from the virtual reality part of CSCW) of impact and support or even intercept cooperative work relations.

In the complex work settings that characterize many service, industrial, and administrative companies of today, cooperative work arrangements emerge as a result of our limited capabilities. The cooperative work arrangement emerges as a response to different and dynamic requirements imposed by the field of work and the wider work environment.

In meeting these requirements the cooperative work arrangement serves to augment psychical and mental capacity, differentiate and combine multiple technique based competencies, facilitate the application of multiple problem solving strategies and heuristics and facilitate the application of multiple perspectives on a given problem (Schmidt, 1990).

A further characteristic of cooperative work in large scale complex settings is that it is often distributed in time and space. In addition the way cooperative work is arranged changes dynamically according to the situations at hand in terms of the actual human and technical resources. Also the cooperative work arrangement does not have to be a stable construction formed to fulfill a certain function but will be formed on an ad hoc basis to cope with particular situations. That is, it does not have to be considered as a particular organizational entities like the team or group or departments. Rather the cooperative work arrangements can span an entire corporation or even among several corporations. These characteristics have been evidenced through several field studies (e.g. Carstensen, 1996 and Andersen, 1997)

In relation to enhance such cooperative relations there is good reason to take a broad look at the design of a supportive work environment in terms of facilities for dynamic room configurations, flexible interior (re)arrangements, establishing distributed meeting rooms and other work spaces, and CSCW technologies in general.

In CSCW much of the work has focused on the study of team-work. The notion of team-work often implies assumptions about a well-defined, relative stable, homogeneous and harmonic work-group. But in less confined ‘real world’ settings this is often not the case. As sociological research has shown there is an inevitable and essential aspect of contingency in cooperative work activities (Suchman, 1987).

A number of sociological studies using ethnographic methods have shown that work is embedded in a sphere of social patterns of non-formal interaction. No matter existing formal prescriptions of work the actors are engaged in and depend on non-formal activities in carrying out their work (Wynn, 1979; Suchman, 1983; Suchman, 1987). Through informal work activities consistent interpretations of the course, structure and contents of work tasks are maintained (Middleton, 1988).

That is, office work is embedded in social settings where the activities are mediated by constant interactive non-formal communication, sharing of materials and tools and is characterized by that workers, in a consecutive way are engaged in supplying co-workers with information regarding their own and others ongoing work activities. As such a main part of office work is constituted by informal conversational activities that mediate the development and maintenance of a consistent and coherent understanding of each others task structure, content and progress. In addition everyday office activities is often performed in very open ended and poorly structured work systems characterized by a high degree of dynamic cooperative problem solving and decision making.

Taking the "Cooperative Building" perspective this means that the contingencies of cooperative work come to play role not only in terms of information technology. They have to be considered in the light of, e.g., architectural considerations of designing open, flexible and dynamic spaces ('real' as well as virtual) even incorporating an esthetical dimension. Emphasis must be placed on the design and construction of building interior, spatial arrangements and pleasant indoor work environments that encompass the social richness and the situated character of the everyday office work activities.

In the research field CSCW a part of the problem space is situated in the work of building bridges between the different scientific disciplines and especially between the social sciences and the application oriented information technological disciplines (Shapiro, 1994). The social sciences can provide knowledge about cooperative work practice and a repertoire of methodologies for obtaining new knowledge of these aspects of human life. Taking a look at the area "Cooperative Buildings" building such bridges becomes even more complex because of the immense amount disciplines involved. This is true in our case as well. Therefore we aim to follow up and evaluate on the process of building office VISION.

In the next section we will present the case of office VISION. The reader must keep in mind that we are still in the beginning of the project. The building will be finished in June 2000. Fortunately, there is still much research and developmental work to be carried out.

3 Office VISION

Fig. 1. office VISION east view

Our basic biological needs are the natural starting point for a sustainable vision of the future, since they will not change much within the next century. The vision is that our true biological, social and psychological needs should be met most directly aiming at minimum resource- and environmental strain. The genius definition of UN's Brundtland commission is that we should live the best possible life without doing it at the expense of future generations. The new concept of "environmental space" adds that the resources should be distributed equally among the global population. Together this add up to a 90% reduction within EU during the next century. It will hurt less if we identify the true needs and develop the most direct and resource conscious way to satisfy them.

Office VISION is a both a building, the framework for innovative office functionality and a complete consulting scheme for the office of the future. Within the office-VISION project, the Danish Technological Institute (DTI) has initiated the development of 4 main themes:

- Sustainable working methods, identifying the true needs and the most direct way to satisfaction.
- Democratic organisation of releasing the gifts and talents necessary to meet the global challenge.
- A healthy indoor environment close to humans evolutionary "design conditions", - a luxuriant tropical island under vacuum glazing.
- Liberating cooperative technologies and new ways of organising work.

3.1 Sustainability

Office VISION is DTI's test case for an entirely new sustainable working method. The most basic questions should always be put first. Which true need does the building satisfy? Could they be satisfied by substitution, e.g. reduced floor space through more flexible utilisation? How can the constructions be minimised? Can renewable/recyclable materials be used in order to save resources? Is the building constructed with modules that can be replaced without having to replace the entire structure? Is it possible to integrate photovoltaics in order to make the building energy producing? Can rainwater and sewage be recycled? Can plants purify the air? Can we build without environmental strain? Office VISION attempts to answer all these and more questions positively.

The brilliance of Brundtland's definition of sustainability is that it includes both environmental, long-term and economical success criteria. It is thus essential that the promising environmental solutions and innovative ideas are developed into systems and components, which are competitive on the global market and due to their minimal size, can be transported far without environmental strain.

The specific objectives are:

- Development of a new sustainable in depth analysing methodology based on true needs.
- Minimal resource consumption and environmental strain in life cycle perspective.
- Energy producing building envelope.
- Local processing and recycling of sewage.
- Competitive, transportable, minimal products for the global market.

3.2 Dynamic democratic organisation

The office is the theatre for organisation of work, but at the same time also for the obstruction of work by way of bureaucracy and formalism. The demand for work organisation increases with the world-wide trade/competition, and globalisation of information/knowledge/capital as well as functional division of labour. In the future, interdisciplinary organisation of the work, focusing on the customer needs, based on democratic teamwork culture and entrepreneur-ship will be a competitive advantage.

The hierarchy was, previously, the only way to organise and communicate information and decisions within an organisation. However that is now a relic from the enlightened despotism. Information technology, Internet and Intranet make an internal free market possible within consultant companies with an innovative entrepreneurial culture. It can facilitate a take over of management, responsibility and initiative by the employees, just as in a democratic society with market economy, ruled by laws, economy, culture and democratic decisions. The most direct way to satisfy a need leads to least possible waste, ecologically as well as economically. This is the kind of sustainable organisation analysed at DTI. The specific objectives are:

- Organisation with the customers need in focus.
- Development of entrepreneur corporate culture based on values.
- Training and cooperative information technologies for a free market within the organisation.
- Law rather than hierarchy regulating the internal market.

3.3 Healthy and inspiring indoor climate

The starting point for officeVISION is that man's evolution has not been able to alter the fact that our ideal climate is something like the climate of the Pacific Islands. We build in order to protect ourselves from the rain, snow, wind, cold, heat, burning sun as well as from our less attractive fellow creatures. However by doing so, we stay in buildings with polluted, dusty and humid air, lacking daylight, and excluded from the many positive impressions of nature. For many people, especially in northern countries, lack of daylight leads to less personal energy in winter (SAD). Returning daylight to their lives will increase productivity. Office VISION aims to achieve the best from both worlds - a luxuriant tropical island under vacuum glazing.

It is important, in an office, to be able to work efficiently. Office VISION is designed to accommodate the many different functions and needs of the employees. Small rooms for individual work, larger group rooms and a large conference room. Multimedia room and room for quiet thoughtfulness. Dark rooms and light rooms. The stage of the theatre is our inspiration. The users create the interior and change it in a jiffy. Special climatic furniture creates an individual indoor climate. The specific objectives are:

- Highly insulated glass building envelope, which lets in the daylight.
- Photovoltaics, which besides from electricity production also shields against too much light.
- Thermal storage, in order to save the coolness of the night for hot summer days.

– Natural ventilation without draught.
– Comfortable acoustics.
– Great flexibility within interior and utility.
– Individual indoor climate by way of climate adaptable furniture.

3.4 Liberating cooperative technologies

One of the most characteristic qualities of mankind is that knowledge is accumulated and disseminated. Language and hence the printed word, telephone, radio, television and the latest, the Internet has accelerated this process. Today the world is just at hand information-wise, including the latest and the most advanced information, free of charge. Now, in the global information society, it is solutions to the global challenges that are in demand, optimal ecological and economical solutions.

The world's leading experts and scientists publish, as part of the academic world's meriting process the leading knowledge as fast as possible, to be there first and achieve recognition. But everybody else is also proud to show off their leading knowledge. Moreover, all patents are published after a few years. In that way the latest and best knowledge is available if you can just find it.

Until now the great problem has been that it is more expensive to find relevant knowledge than to pay for advice from a consultant. But that can change fast. Until now science has mainly been published in scientific magazines. The scientific world wants faster information exchange including photos and graphics presented on the Internet. In a few years it is expected that the bandwidth (transmission speed) has grown about 100 times compared to today.

It takes expert knowledge to question an expert. One thing is to stand with a scientific magazine in the hand, another is to understand it. Even though expert knowledge is free, it is not a free good for the industry that wishes to solve a problem.

The information technology must be reduced to something like glasses, hearing aids and clothes. Something you wear and carry with you, something that strengthens your communication and information processing whenever and wherever. The possibility to use speech is decisive for the mobility. The microphone takes up next to no space and today it is possible to transcribe and/or edit speech. Evidently, small devices also save resources.

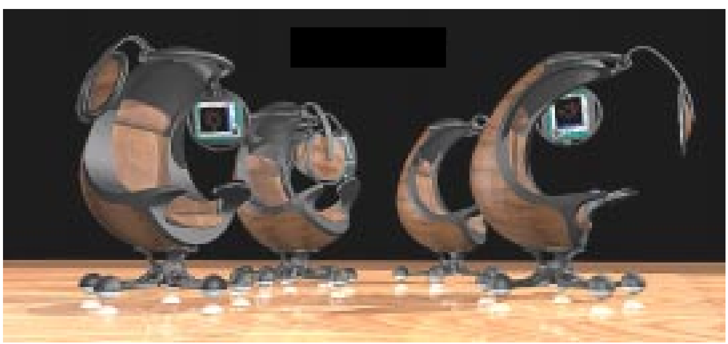


Fig. 2. The office VISION multi media chair

Humans must be in focus. Humans communicate naturally by means of speech, facial expressions and body language. It is imperative that facial expressions and body language can be clearly transmitted. Video-conferencing could substitute business trips, by far the most energy consuming activity of the office. The computer should not be a PC but shared. CSCW applications should be turned in to parts of the operating system to facilitate cooperation. It should be possible to carry out meetings distributed in time and space. The specific objectives are:

- Multimedia team spaces
- Miniature information technologies for optimal mobility/flexibility.
- Cooperative information technologies instead of transport.
- Diagnostic information technology tools.
- Integration of information technology and office interior, e.g. multi media chairs.

3.5 Example projects

In the following we briefly present some central project examples from the main office VISION program which will serve to shed more light on the four themes discussed above.

3.5.1 The power envelope - zero emission building

This project is in specific related to the themes of sustainability and healthy indoor climate (cf. Sections 3.1 and 3.3). The project is supported by the EU Joule program. The main objectives of this project are:

- To develop and test a transparent and high performance energy producing building envelope system.
- To develop and build a zero emission daylight office building.
- To evaluate energy performance and user acceptability of this glazed zero energy building.

This experimental building will utilize newly developed highly insulating evacuated glazing and this project will develop facade integrated multifunctional PV daylight control elements in a new industrialized smart building component system, creating a totally new concept for working spaces. Diffuse daylight covers the passive space heating

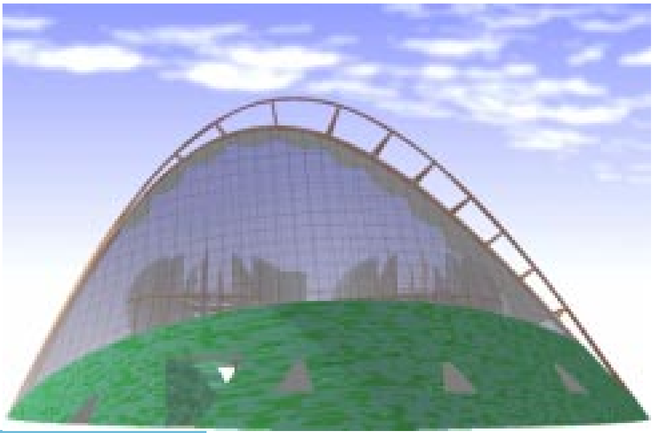


Fig. 3. The thermal envelope

and lighting requirement throughout the day and the year, except in the early winter mornings. Direct sunshine provides electricity. The switching is instantaneous utilizing the optical laws of physics. A life cycle zero energy building, - the *zero emission building* - with supreme working conditions and indoor environmental quality is created. The daylight factor (overcast conditions) is above 50% all over the building compared to 2-10% in conventional buildings. As the only time of daylight in the winter is during office hours. This level of daylight in an office is necessary to prevent Seasonal Affective Disorder problems.

This is not yet another low energy building where a lot of energy saving components and system are added on both building and price. The innovative approach in this project is on the contrary reducing equipment and components to an absolute minimum: Glass on a minimal load bearing construction. No frames, no ordinary building construction. All water/sewage installations in a factory built container. A very simplified electrical installation with smart controls integrated in the (wireless) computer network. Right through an attempt to bring down embodied energy, waste, production cost, and transportation. 3 truckloads brings the whole building and its installations to the site. No cutting is done on site, only assembly. The ambitious goal is furthermore that the cost of this envelope should not exceed 150 ECU/m² in mass production For the PV part, the extra cost should be justified by energy saving with a simple pay back time of 10 years. This new product is thus not competing alone with glazing systems (costing 3-5 times as much) but with all insulated thermal envelopes of conventional construction.

The cross section is determined by the summer sun angle. The south facade gains and processes direct solar irradiation, the gables shade and the north facade is in shadow from direct sunlight until 7pm (summertime) thus not disturbing during normal office hours. The position on top of en existing building is chosen to show urban and retrofit potential of this concept. The existing building is a consumer for the excess energy from this pilot building, a symbol of a retrofit strategy for bringing down the energy consumption of the existing building stock.

3.5.2 @VISION organisation

This project is in specific related to the democratic organisation theme (cf. Section 3.2). The idea behind project is to try to form an new organization which is horizontal, flexible, legally competent to transact business and build on democratic principles. The main innovative contents are:

– A creation of a vertical project organization for a holistic service – taking the task as a point of departure.
– A creation of a horizontal project organization taking resource allocation as a point of departure.
– The project entrepreneurs have full responsibilities for economy and project management.
– Only the results counts - not the time consumption. Only solutions and ”brain-hours” is taking into account – not ”body-hours.”
– Value analysis and control and market mechanisms replace formal government and bureaucracies.

– Internal services will be bought on demand, e.g., accountancy and computer hot-lines.
– A democratically elected management board and securing democratic rights and obligations
– A clear sustainable vision for the work to be carried out.
– Value based, visible and conclusive management
– An authorization for employees based on a trainee solution and comprehensive educational activities focusing on the functional, cultural and value-based aspects of the organization.
– An individual economical incentive.
– A very high degree of flexibility and mobility.

Office VISION will act as pilot forum for trying out such an organization. At sight the goal is to implement some (or all) of the mentioned organizational innovations with in the framework of our own organization as a whole, depending on the evaluation of the pilot.

3.5.3 A woodland kindergarten for adults

This project is in specific related to the healthy and inspiring indoor climate theme (cf. Section 3.3). One of the conclusions in a recent empirical study of children's behavior (Grahn *et al.*,1997) is that children who are nursed in natural environments shows a better ability to concentrate and has a more developed play behavior than children who are nursed inside and who are reduced to play in the city courtyards. Another main conclusion is that children are significantly less ill, and become more supple when nursed in woodland kindergartens instead of city kindergartens. A third conclusion is that the natural surroundings support children's mental efforts in a way planned and organized environments does not. Also the researchers found that the natural environments supports children's intellectual flows by "loosen up their thoughts" and increasing their ability to "think clearly" without being to importunate. The following list of requirements was derived from the study. This list has served as a strong inspiration for us in the project.

1. **Wilderness:** The need to experience the mysteriousness in environment not planned and organized by humans.
2. **Scope**: The patio must be sufficiently big to allow free activities without worrying about violating existing limits and create annoyance to others.
3. **Peace:** There must be a peaceful place to rest and calm down without noise, chatter or obtrusive people.
4. **Wealth of species:** It must be possible to be able to discover new fascinating things that attract attention, are unpredictable and not easy to grasp. E.g., the different seasons of the year.
5. **The open space:** There must be an open space where to gather.
6. **The playground:** A place to make experiments and to be active.
7. **Fête grounds:** A place for festive occasions, cosines and entertainment.

8. **Cultural heritage:** A place to experience examples and symbols from our cultural and historical heritage.

The common theme for office VISION is that people are different and have different needs. This is also the reason why we have chosen both to have some psychical flexibility and at the same time within the climatic shield to offer a wide range of functional flexibility and expedient flexible spaces. This allow people to choose to live a normal office life in office VISION and from that starting point to develop new habits. The interior program contains 3 different environments: The Garden, the Caves and the Office modules.

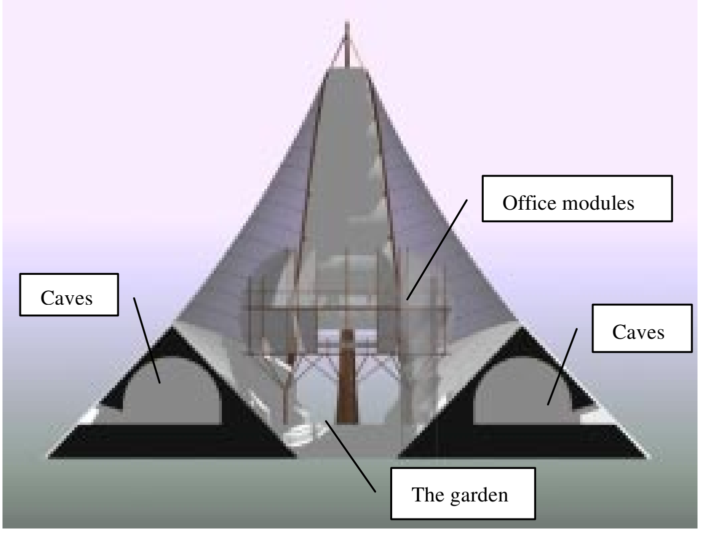


Fig. 4. The Garden, the Caves and the Office modules

Within the garden: On top of the caves there will be a layer of gravel mixed with cement. Moreover there will be a layer of ochre sand, which is shaped as a soft natural landscape. Here the big plants will be planted in pipes leading directly through to the ground water. These surface of pipes will be covered with Leca (light expanded clay aggregate reg. trademark.) The idea is to let all it all look and function like an oasis, but without water or soil at the surface. In this way we avoid unhealthy microorganisms. All plants are placed in this "common" - the botanical gardens. It is possible to take a walk in the garden and sit down in the shadows of the trees. In the middle of common you will find the cafe. In the large glazed garden the climate is bright and rather fluctuating, somewhat like outdoor on the Canary Island.

Within the caves

Mounted directly on the base gravel foundation there will be a series of domes made of fiber reinforced concrete. These domes are outwardly connected to the surroundings by large pipes with glaze doors into the open. Inwardly the domes are connected through doors leading into the landscape of plants within the glaze climatic shield. It is important to have to create a good sound protection to prevent noise to go in and out of the domes. Daylight is not that important within the caves as in the open office landscape, as the domes are meant for e.g. multi-media team activities and presentations. Stainless steel pipes transmit light both from the outside and from the garden into the caves. These pipes will also be used for different ventilation strategies and purposes.

Within the office modules

The open plan office is great for getting help from ones collages. The cell office is great for concentrating on your work when you know what to do. In office VISION the office modules are designed to serve both purposes. They can be open plan when and if you want and they can be closed when that is convenient. Actually they can even be only acoustically closed by glass walls and fully closed by additional curtains. The glass walls are of similar construction as glazing of balconies, and they are covering all walls. You can open towards your neighbors, toward the garden and toward the entrance atrium between the offices. In the office modules the indoor climate is individually controlled.

Overview of the office VISION interior program	Area m^2	Persons	Floor
Garden			
1. Entrance hall	10		1
2. Guest meeting room 1	15	6-8	1
3. Guest meeting room 2	15	6-8	1
4. Garden		20	2
5. Garden café	100	60	2
6. Swimming pool	100	6	1
7. Sport facilities	60	6	1
8. Forum	50	50	1
Caves			
9. Multimedia team space 1	50	10-12	1
10. Multimedia team space 2	50	10-12	1
11. Conference room	50	20	1
12. Library	50	6-8	1
13. Workshop	50		1
14. Room for technical installations	50		1
15. Siesta room 1	8	1	1
16. Siesta room 2	8	1	1
17. Changing room/sauna ladies and gents	100	8	1
Office			
18. Office modules	300	50	2+3
In total	1100 + garden	50-60	

Fig. 5. Overview of the office VISION interior program

3.5.4 Multimedia team spaces

This project is in specific related to the liberating cooperative technologies theme (cf. Section 3.4). In the future, work and co-operation in organizations will be characterized by a high degree of dynamics, flexibility, and mobility that will go far beyond many of today's developments and examples. This project aims to adapt and integrate different multimedia IT components and systems to be tried out and demonstrated in the DTI officeVISION building and our other local DTI offices In this project, we will especially focus on integrated support for local and global co-operation situations. It addresses the issue of how important it is to support local communication and co-operation activities, e.g., co-located in a room or in an office building, versus globally distributed people working in different locations. The project is inspired by the work of Streitz *et al.* (see e.g., Streitz *et al.*, 1997). The overall goal of the project implies the following results:

– A working demonstrator of an integrated multi media workspace of the future
– Value adding to industry tools by integration of and adaptation of existing multimedia technologies, e.g., user interfaces, standards and content.
– User experience with value added tools in a real working environment and experience with work re-organization.
– Designing a real space from a multimedia and social point of views and integration of the multi media tools and a healthy environment
– Implementation of "Creativity Labs" utilizing know-how and technology acquired through research/developments done by GMD-IPSI, Siemens and DTI over the last five years.

The demonstrator will be created in a business situation, where consultants are doing their normal job, i.e. solving problems for real customers in distributed teams covering a range of co-operation scenarios.

References

1. Andersen, H. H. K.: Cooperative Documentation Production in Engineering Design. The 'Mechanisms of Interaction' Perspective, *Topics in Cognitive Science and HCI*, Centre for Cognitive Informatics, Risø National Laboratory/Roskilde University, No. 9, (1997).
2. Carstensen, P. H.: Computer Supported Coordination, *Writings in Computer Science,* Computer Science Department, Roskilde University, No. 61, (1996).
3. Grahn P., Mårtenson F., Lindblad B., Nilsson P., Ekman A., *"Ute på Dagis"*, MOVIUM, The Swedish University for Agriculture, Sweden, (1997).
4. Middleton, D.: Talking Work: Argument in Co-ordination and Improvisation in Team Work, *Summer Conference on Work and Communication, University of California; San Diego; California*, (1988).
5. Schmidt, K.: *Analysis of Cooperative Work. A Conceptual Framework*, Risø National Laboratory, June, (1990).
6. Shapiro, D.: The Limits of Ethnography: Combining Social Sciences for CSCW, *CSCW '94. ACM 1994 Conference on Computer Supported Cooperative Work, Chapel Hill, North Carolina, USA*, edited by T. W. Malone, ACM; USA, (1994), 417-428.
7. Streitz, N., Rexroth, P., Holmer, T.: Does "roomware" matter? Investigating the role of personal and public information devices and their combination in meeting room collaboration. In: *Proceedings of the European Conference on Computer-Supported Cooperative Work (E-CSCW'97)*, Lancaster, UK (September 7-11, 1997). Kluwer Academic Publishers, Dordrecht (1997) 297-312.

8. Suchman, L. A.: Plans and situated actions. The problem of human-machine communication, Cambridge University Press, Cambridge, (1987).
9. Suchman, L. A.: Office Procedures as Practical Action: Models of Work and System Design, *TOIS*, 1(4), (1983), 320-328.
10. Wynn, E.: *Office Conversation as an Information Medium,* Ph.D. dissertation, University of California, Berkeley, CA, (1979).

Future@Work
An Experimental Exhibit Investigating Integrated Workplace Design

Robert Hunt

Barclay Dean Interiors
1917 120th Ave NE
Bellevue, WA 98005, USA
Email: bob.hunt@barclaydean.com

Andrea Vanecko

Callison Architecture, Inc
1420 5th Ave #2400
Seattle, WA 98101, USA
Email: avanecko@callison.com

Steven Poltrock

The Boeing Company
P.O. Box 3707 M/S 7L-49
Seattle, WA 98124, USA
Email: steven.poltrock@boeing.com

Abstract. A non-profit consortium developed an integrated workplace exhibit to investigate how the workplace should evolve to support changes in technology and social and organizational structures. The exhibit helps people visualize and experience new and innovative office designs. The needs of a fictitious company form the framework for the design. It is divided into two sections called 1997 and 2007. The 1997 section demonstrates *evolutionary* changes to offices in both space and technology, enhancing traditional design concepts and introducing elements of flexibility and choice. The 2007 space introduces a more *revolutionary* approach to office design, work practices, and technology. The primary purpose of the office is expected to be support for socialization and group work, with technology powerfully providing the information required for these efforts. More than 1,000 people have toured the exhibit in the few months since its opening. Many organizations have been strongly influenced by the exhibit, searching for ways to integrate its concepts into their plans for future office space.

Keywords. experimental exibit, integrated workplace design, office design, future office space, group work, socialization

1 Background

The work environment is changing. *The New York Times* reported a five-fold increase between 1984 and 1995 in the number of people who work from outside the office. About 18% of U.S. companies allow telecommuting while 30% offer flextime. With technology revolutionizing the way in which people work, real estate costs rising, and regional infrastructures stretched to the breaking point by population increases, the office must adapt to support these changes.

About two years ago several people in Seattle, Washington were discussing how the changing nature of work might impact office design concepts. The group observed that many people were talking about the need to redefine workplace strategies, but there were few, if any, places to see or experience new work environments. A place was needed where new approaches to workplace design could be tried and experienced. This vision gave birth to the Future@Work exhibit.

The group formed a non-profit consortium and embarked upon designing and building an experimental exhibit. The problem of a location for the exhibit was solved when Seafirst Bank donated 465 m^2 of office space in downtown Seattle for 1 year.

Some of the organizational trends motivating the exhibit were as follows:

- ❏ Information technologies have changed the ways people work dramatically. The tools of work have changed, and people can collaborate with one another from a distance.
- ❏ Organizations have re-engineered their business processes, flattening levels of managerial hierarchy.
- ❏ Organizations emphasize group work of multi-disciplinary teams over the individual work of people performing functional tasks. These teams bring together the people, regardless of functional division, needed to support their requirements.

Despite changes in technology, organizational structure, and ways of working, most organizations design office environments as they did 20 years ago. Some of the characteristics of these traditional space designs are as follows:

- ❏ Facilities are designed predominately around individual space allocations with little consideration for support of teamwork.
- ❏ Real estate is allocated based upon rank in the organization, not function. Additional space is provided as a reward for rising in the hierarchy. It is allocated as a symbol of status, not in response to functional needs.
- ❏ Facility managers are rewarded for cost control, not for using space in a way that enhances the productivity of the workforce.
- ❏ Facility design and infrastructure is relatively inflexible and expensive to change, a poor fit with the rapid changes in team structure found in many organizations.

2 The Collaboration

Future@Work represents an achievement in corporate collaboration. More than 100 companies contributed to the exhibit, with seven core companies (AT&T Wireless Services, Barclay Dean Interiors, Callison Architecture, Steelcase, Metro Furnishings, Sparling, and Seafirst Bank) forming the nucleus of the collaboration. The consortium members contributed more than $1,000,000 despite having no clients for the exhibit. This collaboration made the exhibit a unique experience for the consortium members before the doors of the exhibit opened.

The group that conceived Future@Work represented firms from the real estate, architectural, and commercial furnishings industries, each concerned with different aspects of the physical workplace. They recognized that effective workplace design requires consideration of other influences. The underlying roots of change causing the need for a redefinition of physical space are found in advances in information technology and corresponding changes in organizational structures and processes. To consider these influences, we adopted a model promoted by Steelcase (see Duffy et al, 1993; Duffy, 1997) that includes four major areas: *Business Process*, *People*, *Technology*, and *Workplace*. In this model an interrelationship is developed that defines all organizational performance as the result of *People* organized by *Business Processes*, who are supported by *Technology* and perform work in a *Workplace*.

With this model in mind we sought to expand our collaborative team to include members representing expertise in each of these four major areas. We began talking to organizational leaders about business processes and structures and about the impact, challenges and results of process reengineering. We sought partners from the technology arena who could lend their expertise on how emerging trends in IT were impacting organizational productivity. We sought expertise and insight into people's ability to effectively embrace and adapt to changes in business process, technology, and physical space. We involved members of the Human Resources and Organizational Psychology fields with insight on how new work strategies might affect organizational culture.

3 Exhibit Goals

The consortium sought to build an environment that integrates and leverages physical space and technology to support and enhance an organization's effectiveness and to support collaborative group work. It soon became apparent that myriad issues spring from this vision. We needed to define key goals for the exhibit and determine, based upon these goals, how to proceed in its development. After several months of conversation and debate we adopted the following goals and themes.

3.1 Interrupt people's thinking

The exhibit should break people's traditional frames of thought and provoke them to reconsider some of their basic approaches to organizational change and evolution. This is why we felt compelled to build a space. It is much easier to reconsider a viewpoint when experiencing something new.

3.2 Explore the benefits of an integrated approach to change

We believed many gains could be achieved by executing organizational strategies that systematically integrated the interrelationships between the fundamental business factors of People, Process, Technology and Workplace. However, in practice change is rarely approached using this methodology, particularly in larger organizations.

Business leaders talk about cross functional change processes, but most organizations separate the execution of strategies in Real Estate & Facilities, Information Technology, and Human Resources. These groups may all be trying to support the same strategic vision or business process, but they rarely talk to one another about how their worlds might be interrelated. While developing the exhibit we were amazed at how often the collaborative partners representing separate disciplines (who generally had never collaborated with one another before) would discover their professions were trying to achieve the same strategic goals using different approaches and tools.

3.3 Demonstrate activity-based planning methodology

When allocating real estate, organizations tend to focus on who you are, not what you do. We wanted to explore a methodology that first supported what people do in the organization, both in individual and grouped based activities. Without discounting the influence of culture and status in the organization, the group believed that effective environments should first serve the diverse activities of organizational populations, regardless of rank.

3.4 Provide an inspiring experience

We sought to create an environment where people feel at home at work. An exciting, inspiring environment should help organizations attract and retain first-class talent.

3.5 Explore creating an environment of choice

A flattened, cross-functional, process-driven organization is fluid. Teams evolve to meet changing goals and needs. Teams may span geographic locations and organizational structure. We wanted to explore technologies that support teamwork through enhanced communication and through easy access, exchange, and manipulation of information. Concurrently, we wanted to explore physical settings that support diverse ways of working while maintaining or reducing overall real estate requirements.

3.6 Support collaboration

We sought to explore group collaboration on two fronts: Collaborative efforts occurring within the confines of a given space, and collaboration that occurred across geographic boundaries supported by a variety of different electronic tools. Also, we were concerned about the behavioral implications of collaborative work and how it could best be encouraged and facilitated within the workforce and over a wide range of mediums, both physical and electronic.

3.7 Support cultural and organizational change

We wanted to develop ways in which changes in work factors can be easily learned, embraced, and implemented. New technologies and facilities intended to enhance the productivity of the workforce can be ineffective or harmful if people do not embrace and effectively utilize these new tools. New methods of work require new behaviors for the workforce, and change tends to be resisted. Significant changes in work strategies impact existing cultures, particularly when tinkering with underlying symbols of status. We sought to examine how changes in technology and physical settings could be introduced in ways that support desired organizational cultural attributes and mitigate negative cultural reactions to change.

3.8 Demonstrate return on investment

Modern organizations evolve continually, but facilities do not support change. Rigid interior architecture, utilities infrastructure, and system furnishings increase the cost of changes. The exhibit explores ways of reducing costs through adaptable facilities and through technologies that enable individuals and groups to work in locations other then the central office. Some areas considered include:

❑ Reductions in real estate allocated per employee
❑ Better utilization of existing space
❑ Increasing the flexibility of interior architecture, utilities infrastructure, and technology
❑ Ergonomic factors that support worker productivity, health, and safety
❑ Work strategies and work environments that support the quality of people's lives and reduce turnover
❑ Application of an integrated workplace strategy that supports organizational performance goals

4 The Exhibit

We divided the space into two sections, one called 1997 and the other called 2007. The 1997 section of the space was designed to display *evolutionary* changes to offices in both space and technology. The space enhances traditional design concepts, and introduces more elements of flexibility and choice into the environment. The technologies are readily available and most have been adopted by more aggressive companies. The design of the 2007 space takes a more *revolutionary* approach to office design, work practices, and technology. Here, too, the technologies are readily available, but few companies have adopted them as of now.

Fig. 1. The layout of the Future@Work exhibit

When designing these spaces we faced a serious challenge. How could we employ activity-based planning methodology without a client or target business? To meet this challenge we created a fictitious company named Humboldt Home and Hardware. The exhibit thematically explored a ten-year evolution of Humboldt, a regionally based high end hardware company with plans for national and ultimately global expansion. The creation of Humboldt added a dimension of business reality to the exhibit, allowing us to create Humboldt employees who could, via multi-media production, simultaneously demonstrate the technology we were displaying and subtly deliver messages about the changing nature of work.

Future@Work was designed to be inspiring, providing employees with a comfortable, more residential feel compared to traditional offices. The intent was to create an environment with the warmth and appeal of a local coffee shop or favorite bookstore. We wanted a place that people would want to come to.

Almost all areas, (workstations, offices, conference areas, etc.) are smaller then the typical office space. To demonstrate the potential return on investment, the exhibit shows that organizations can reduce real estate and still create comfortable, enticing environments. We reduced personal space in exchange for increasing group space allocations to support collaboration. The premise was that the exchange could not increase overall real estate.

5 Year 1997

The 1997 section of the exhibit is divided into four separate areas or vignettes: The entry area, the 1997 conference area, the 1997 team area, and a private office.

The entry area (area 1 in Fig. 1) provides a reflective setting where visitors can relax and begin to contemplate change. The entry room is a large, softly lit oval. Curtains frame one wall, and memorable quotes about change are displayed on another. Sample quotes include a 1949 statement by Thomas Watson, Chairman of the Board of IBM, claiming “I believe there is a market for maybe five computers in the world” . The message is simple: change occurs rapidly, it is embraced quickly, and, in hindsight, to imagine otherwise seems silly.

The conference area (area 4) illustrates how simple changes can make a traditional conference room more flexible and support a variety of interactions both within the space and remotely via technology. The conference room has the following features:

❑ Soft indirect lighting to create a less harsh environment and better support the use of multimedia and video-teleconferencing.
❑ A 3.7-m conference table on wheels that breaks into three sections to support break-out groups.
❑ Large multimedia cabinets built as furniture that can be moved instead of destroyed if the needs of the company for the space change.
❑ Vertical surfaces where information can be tacked.

The conference room has been pre-wired for a variety of technologies (Cat 5, T1 lines, and fiber). All power and data plugs are readily accessible and located in walls or on top of the conference table.

During tours of the exhibit we show a simulated virtual meeting between the CEO of Humboldt and his real estate director. We demonstrate how they can use Intel ProShare video desktop conferencing technology to show a video clip of a potential space for a store site and interact remotely while editing a floor plan. The message of this technology is to introduce the power and affordability of remote collaboration via technology that is readily available.

The 1997 team area (areas 6, 7, and 8) demonstrates an environment of choice that supports both individual and group work within a small space (32.5 m^2). A spine of workstations supports the needs of 3 to 4 people. These stations combine both fixed and mobile elements to provide for individual worker flexibility. Adjacent spaces illustrate how work is performed in a variety of modes and are best supported by different environments. The architectural features of this space include the following:

❑ Highly mobile furniture (including tables, chairs, storage carts, files, etc.) that can be easily reconfigured in a variety of ways by the team occupying the space
❑ A small personal space, owned by the work team, that provides total privacy
❑ Mobile partitions and screens that act as barriers and provide display and writing space

❑ Adjustable ambient lighting and window treatments to control light levels and reduce glare on computer screens
❑ Acoustic partitions, acoustic ceiling tile, and zone-controlled white noise

In exchanging individual spaces for group space, personal workstations are only 3.7 m^2 (typical designs are 6 m^2 or larger). To create a more inviting environment and to lessen the sense of enclosure, the colors used are softer and more residential then found in traditional designs. To further create the illusion of more space the team area is located next to the outside windows and there are no barriers separating the individual workstations from the shared team space.

The collaborative team area introduces the concept of wireless technology in the office. The entire exhibit is a micro-cell site provided by AT&T Wireless. The office's wireless phone system operates like a PBX system. All calls can be transferred using a 4- or 5-digit extension number, and within the confines of the facility there would be a flat monthly fee structure for services, as with wired systems. However, if a person were to leave the office they would still use the same phone, they simply would change billing rates. Once free from the anchor of a fixed communications device, people can work effectively anywhere in the environment.

Other technologies employed in this area include the following:

❑ A large electronic white board that is networked into the office infrastructure so that recorded information can easily be disseminated
❑ A company intranet
❑ A web based system called *Reserve* for remotely scheduling resources within the organization (meeting rooms, AV equipment, vehicles, food, etc.)

The 1997 private office (area 10) is usually empty. Recent studies show that private offices are empty about 70% of the time. This represents a lot of idle, expensive real estate. We attempted to reduce office size (only 8.8 m^2) yet still make it comfortable. The strategy was to maximize the use of vertical space for both storage and work surface. We introduced a large wall unit for vertical storage space. An electronic whiteboard on another wall provides a vertical work space. The office desk is light in scale and can double as a conference table. We softened the walls with textured wall coverings to lessen the feel of physical barrier and used softer lighting to add texture to the environment.

Empty private rooms should be reusable as collaborative meeting spaces, raising issues of personal and professional security. The wall unit has a fold-down door that can easily be lowered to secure the worksurface or raised and locked to secure all storage in the unit.

6 Year 2007

Designing for the year 2007 requires anticipating the coming changes in technology and the business environment. Some of the anticipated changes are:

❑ Information technologies will continue to increase in power and richness of application.

- ❑ Wireless technology will untether computing and communication technologies from fixed locations.
- ❑ Large interactive display devices will support collaboration in the office.
- ❑ People will perform complex individual and collaborative work from a variety of locations other than the office itself.
- ❑ People will go to the office less and work away from the office more, reducing the percentage of workers in the office.
- ❑ Quality of life will be an increasingly prominent issue.

These trends point towards a changed mission for the office. We see the emergence of an office whose main mission is to support socialization and group work, with technology powerfully providing the information required for these efforts. Though individual work will still be performed at the office, it will not be the central focus. By 2007 we anticipate a reduction in personally allocated individual space. Individual spaces are still available to perform work, but they are more often borrowed, not owned.

We feel that the workforce must perceive that they are gaining something to counteract their fears of change and sense of loss experienced by reductions in personal space and symbols of status. There must be an exchange for the changes to be embraced.

In designing for 2007 we attempted to offer the workforce an exchange that is analogous to moving from a basic one-room, one-person apartment to a large, diverse, and well-designed home shared with others. We approached the design of the office space with none of the constraints or preconceived notions of traditional office design. We created a diverse collection of experimental spaces to support different ways that people work. We attempted to make the office a place where people would want to come by designing areas that, though smaller, are more comfortable, attractive, and gracious than traditional office environments. Our goal was to create laboratories that would stimulate new thinking about the workplace.

6.1 Reception area

A concierge (in area 11), not a receptionist, greets the visitor to the 2007 space. The concierge assists people returning to the office to access the resources they need, including office space, and to provide them with an opportunity to be positively reacquainted to the culture and activities of the organizational community.

Employees have lockers for storing personal files and effects, supporting a common cultural need for individual attachment to the environment. Lacking a permanent space, employees can arrange their personal items in whatever space they use. An organization with a cultural need for visible symbols of status could give higher-ranking employees access to private offices and allocate workstations to all others workers.

The reception area contains a 107-cm plasma screen, a high-resolution, thin video monitor that hangs on the wall like a piece of art. This display provides touch screen access to the company's web site, allowing visitors to search for information desired about the company.

6.2 Village Green

The 2007 space includes a village green (area 12), a large meeting area. The village green is similar in feel to a nicely appointed hotel lobby or the common area of a first-class resort. It is purposely designed to entice people into having lively and informal meetings. The village green is highly flexible; all its furnishings are mobile, including tables, chairs, display boards, and storage units. Even the lighting is flexible and is suspended on mobile tracks in the ceiling.

The village green is supported by wireless data and communication technology. A visitor can access information on the company network from anywhere in the space by simply turning on a laptop computer. The visitor can remotely control the large video monitors on the walls of the space and remotely print and transfer information.

A company *dashboard* on one wall of the village green displays broadcast messages. The dashboard is a large, high-resolution, computer-generated display, easily viewed without dimming the surrounding lights. It can be used to display critical organizational information, presentations, or remote video-teleconferencing.

6.3 Alternative Work Settings

Work settings adjacent to the village green demonstrate diverse approaches to supporting specific modes of group or individual work. These work settings interrupt visitors' thinking about office space and stimulate ideas regarding choices in the office environment. The settings include a private office, workstations, a decompression room, a juice bar, a small multi-use room, and a study.

The private office (area 10) is simply a back door to the same office shown in the 1997 space. We feel offices still will be around in 2007, only now they may be borrowed rather then owned.

The 2007 workstations (area 14) require less storage space than in 1997 because information is stored on and accessed from compact digital media. Wall-mounted display tools replace the storage areas and provide better visual access to information.

In the information age people are assaulted by information and rarely have time to reflect. An employee who needs a quiet area to think or simply relax might enter the decompression room (area 15), a small (2.2 m^2) softly lit room containing a comfortable lounge chair. The room (about the size of a broom closet) purposely contains no technology.

The juice bar is a small bistro-like area (area 18) designed to encourage quality interactions in the context of food and drink. This area serves informally to support the culture of the organization. Visitors will see pictures on the wall of employees in non-work situations. Employees can post messages on an informal electronic bulletin board (a plasma screen) and watch a video clip of a company picnic.

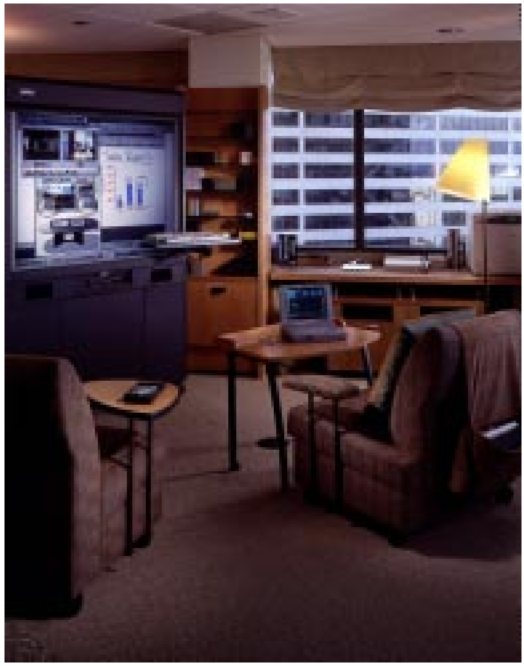


Fig. 2. The 2007 study

A small (only 7 m^2) multi-use room (area 17) provides an attractive and flexible environment for either individual work or small meetings. The layout of the room was influenced by yacht design; objects are downsized and every bit of space is utilized. This space is best appreciated through experience, and it generates some of the most dramatic and positive responses from visitors.

The study (area 13) is an evolution of the 1997 conference room but feels more like a comfortable living room (see Fig. 2). Several small mobile tables (similar to a TV tray) move with the user or are attached to chairs, eliminating the need for a large central table. A key element of the room is a large interactive multimedia display occupying only 1.1 m^2 that supports collaboration among people in the study and with people at other sites. Presentation and production tools are accessible to everyone in the study.

7 Results

People have reacted to the exhibit with excitement and enthusiasm. More than 1,000 people have visited the exhibit since it opened in June 1997. They represent organizations of all sizes and span many disciplines. The people who have reacted most positively have been from large organizations whose process structures are characterized by multidisciplinary teamwork.

The exhibit is nearly half through its planned one-year life. Ideally, its success should be measured in terms of the changes it invokes in the organizations that have visited it. Here we offer a preliminary evaluation based on the exhibit's stated goals. The data for this evaluation are incomplete and mostly anecdotal but provide some measure of its success.

7.1 Interrupt people's thinking

Nearly every tour of the exhibit provokes serious conversation with visitors. Most visitors want to return with key decision-makers within their organizations. These responses have served to validate the power of the experiential nature of the exhibit. Most visitors comment that they never would have understood the possibilities of new approaches to the workplace had they not actually come to experience the exhibit.

In many cases tours provoke action. Several organizations, well under way with large projects taking traditional approaches, have stopped the projects and are now reevaluating their entire design along the though processes demonstrated. Members of the collaboration are now involved in a variety of projects that are assisting organizations to apply these concepts to their own situations.

7.2 Explore the benefits of an integrated approach to change

The exhibit was designed and developed by a collaborative cross-functional team. Technologies are integrated into the physical space, and this union supports greater flexibility in ways of working together. Inspired by this exhibit, a large manufacturing company established a team to design experiments within their own environment. The team includes facilities management, organizational development, network specialists, and experts in collaborative work and collaborative technology. They are planning new work environments that integrate and stretch the limits of all their disciplines.

7.3 Demonstrate activity-based planning methodology

We could not employ all aspects of activity-based planning during the design of the exhibit because it does not support a real workforce. Instead, we focused on the imagined activities of the Humboldt Home and Hardware employees. The work areas were designed to adapt flexibly to a wide range of work activities.

We are now beginning to work with clients to employ this methodology in the workplace. One example is a large recreational product developer that requires their workforce to transition from group work to individual tasks continuously during the development of products. Here we have the opportunity to employ interviews, prototypes, and other methods for involving the workforce in the evolution of their environment.

7.4 Provide an inspiring experience

One large international manufacturing firm has sent more than 50 people (including several Senior Vice Presidents) through the exhibit and is using the exhibit's messages and methodologies as the template for them to reevaluate their overall workplace strategy. A visit of a Navy Captain, led to the visit by the Admiral, which led to the visit by the Undersecretary of Defense for the United States. While most visitors have been from the Seattle area, one large company based in California has sent a series of representatives from strategic geographic locations to the exhibit. They are using it as a tool to provoke and inspire change throughout their organization.

7.5 Explore creating an environment of choice

The visitor to 2007 is met with a range of intriguing options, each of which supports a variety of functional needs. We created flexible environments that could support both groups and individuals in various communication and production modes.

The Director of Organizational Development for a large manufacturing firm, who considered himself somewhat a student of alternative workplace strategies, commented while in the Village Green: “After reading *Workplace by Design* (Becker & Steele, 1995) I thought I knew what environments of choice could do in supporting work, but only after touring this exhibit do I understand how they can feel. I feel like I am sitting in the space written in his book.” Currently this person is employing many of the concepts of the exhibit in an upcoming move for his group. Further, since his group provides high level executive training and cultural management, he is looking for his environment to become a tool in supporting leadership development, learning, and cultural communication.

7.6 Support collaboration

The chief Operating Officer of a rapidly growing high-technology firm of approximately 500 employees laughs out loud while in the 2007 meeting room. When asked to comment on his laughter he said: “ I was just contemplating that I recently spent over $15,000 to take our executive group to a local resort to sit in an environment much like this. I felt a comfortable and informal atmosphere would more effectively support barrier free interaction. This is despite the fact that the technology support for such a meeting was better provided at our own office. I am struck by the realization that this is an admission that the real estate we pay for every month is ineffective in supporting quality interactions.”

Through participation in this exhibit the organizations responsible for technology and facilities recognized the potential impact that they could have on their customers by collaborating with one another. They have now formed a working committee and are integrating their efforts. The Future@Work consortium is facilitating these efforts.

7.7 Support cultural and organizational change

During the short life of this exhibit, our efforts have progressively shifted toward helping organizations understand how they can best employ its ideas and principles. We are helping them develop phased implementation plans. One of the key issues these organizations face is fear of the new workplace. People worry about losing their private workspace and symbols of status without gaining any personal benefit. The exhibit helps people see that the new workplace can be an attractive, fun place to work, and their fears are transformed into anticipation.

7.8 Demonstrate return on investment

An almost universal reaction to the Future@Work is its comfort and warmth. Rarely do we hear negative comments about the reduction in size of almost every space. This both validates our message that individual spaces can be downsized in exchange for more diverse shared spaces, and that good design allows you to shrink real estate without conveying a sense of loss to the user.

This effect was so compelling for one international law firm that they requested an analysis of a planned additional real estate investment to expand their office space. Our analysis showed that by reconfiguring their existing office space, they could simultaneously create a more pleasant, more functional environment, while eliminating their need for increased space. This alternative saved them a lot of money; reconfiguration costs were estimated to be $1.5 million while the cost of additional space was close to $5 million.

8 Conclusion

We have seen some consistent messages emerging from the many visitors to the exhibit. First, the power of an experience is much more compelling than a drawing, book, or conversation. Many people had heard or read about these ideas. But a common statement was, "Unless I had come here and experienced it, I could not have imagined how exciting it could be."

None of the collaborative partners anticipated how strong the interest would be in the concepts represented in the exhibit. Despite many individual differences, organization have reacted similarly, wanting to embrace and implement these concepts. The challenge for the consortium has shifted from communicating the concepts to providing a map or bridge that can help organizations make these transitions. As a result members of the consortium are now involved at a variety of levels in providing consulting support to companies who have determined that they should rethink their workplace strategies.

Acknowledgments

We thank the Future@Work consortium and their extended partners for their dedicated effort in integrating quality solutions for people and organizations.

References

1. Becker, F. & Steele, F. *Workplace by design*. Jossey-Bass, San Francisco, 1995.
2. Duffy, F. *The changing workplace*. Phaidon/Chronicle Books, 1993.
3. Duffy, F., Laing, A. & Crisp, V. *The responsible workplace: The redesign of work and offices*. Butterworth Architecture, Oxford, 1993.

Connecting Qualities of Social Use with Spatial Qualities

Rüdiger Lainer

Academy of Fine Arts, Vienna
Office: Reisnerstrasse 41, A-1030 Wien, Austria
Email: Ruediger Lainer@blackbox.at

Ina Wagner

University of Technology, Vienna
Argentinierstrasse 8, A-1040 Wien, Austria
Email: iwagner@pop.tuwien.ac.at

Abstract. This paper combines work practice research (CSCW) and architectural design & planning for discussing cooperation-support. A specific vocabulary for talking about cooperation is introduced: transformation layer, intermediate space, vista and social transverse. It is used for analyzing people's needs for places and boundaries on the one hand, for boundary crossings and the adaptability of spaces to temporary and unforeseen uses on the other hand. We illustrate our approach by a system prototype-in-design, based on the metaphor of 'Wunderkammer', a 3D multimedia environment for assembling inspirational objects.

Keywords. CSCW research, architectural planning, social use, spatial qualities, 3D multimedia environments

1 Introduction

The idea of 'cooperative buildings' can be approached from different angles and on different levels. The purpose of this paper is to explore the boundaries between work practice research and architecture, with the objective of designing spaces for cooperative activities in mind. The language of space has been developed within different domains, mostly within architectural design, urban planning, and, more recently, by scholars of cultural studies and social geography. It has been connected to themes dealing with power, knowledge, gender, and social practice (e.g. Gregory, 1994; Harvey, 1990; Probyn, 1991). While the language of space is highly developed, there has been comparatively little research on social use in relation to space. Here we think that work practice research (Blomberg *et al.*, 1993; Jordan, 1995) offers a vocabulary for talking about social use from a CSCW perspective.

We will unfold our arguments in two steps. We will

– examine the relationships between the qualities of designed and built spaces and the activities and events that take place in them, seeking to find out how particular qualities of social use can be supported through the design of appropriate places and spaces,
– discuss an example of cooperative work spaces - the design of an electronic 3D multimedia environment for assembling 'inspirational' objects, contexts and metaphors.

Our paper is 'grounded' in different kinds of practice. Our main source is extensive field work on architectural design and planning. We look at the work of architects as socially organized, embedded in context, with a strong focus on experimentation, and at design practice as open, flexible and informal (Lainer & Wagner, 1997). In addition, we draw upon material from field work of how people use electronic work environments, among them nurses (Wagner, 1995), radiologists (Tellioglu & Wagner,1996), and teleworkers (Kompast & Wagner, forthcoming). Interlinking these two sources of experience and analysis also allows us to build and explore connections between the design of built spaces and the design of networked computer systems.

2 Conceptualizing Social Use in Relation to Space

Conceptualizing 'social use' in ways that are relevant to both, architects and system designers, means amongst other things to extend the possibilities of translating desirable qualities of use (as identified in ethnographic studies of work) into spatial qualities. Although a central planning requirement within architecture, social use is an almost peripheral category, and often ultimately reduced to function. The notion of *function* is based on specific cultural codes concerning the distribution and regulation of human activities and social relationships. *Social use* or *use-as event* emphasize the changing, evolving, temporary and sometimes performance-like character of activities (in contrast to the more stable, recurrent, and univocally located nature of other activities). This is resonant with Tschumi's idea of "architecture not as an object (or work, in structuralist terms), but as an 'interaction of space and events'" (1981, in Nesbitt 1996, p. 159).

CSCW research has identified several characteristics of cooperative work, amongst them:

– *Regions and connections*: Crucial aspects of work spaces are their connectedness and zoning. A place may be directly connected to others, or by people's migrations and transitions between them (or established as an enclosed site). It may be subdivided into areas that have been designated to specific persons and activities, contain more 'private' and more 'public' spaces. This is partially captured by the term 'regionalization', which refers to the internal physical, social or organizational boundaries of a specific place. Creating (spatial) regions allows to accentuate, solidify, and create differences of work practices and knowledge's, of culture and identity. While supporting existing power structures and dependencies, regionalization can also be seen as an attempt at protecting special locations and the vision they provide from powerful, potentially overriding views and interests (Clement & Wagner, 1994).

Qualities of Use	Spatial Qualities	Design Approaches
– Connections	– connections and their quality (e.g. easy to establish or remove, multisensual, reciprocal, simultaneous) – intimacy, closeness, embeddedness – regions & hierarchy	– *Transformation layers* as mediating between spaces (e.g. inside/outside) – *Place* (as regionalized, bounded and specific) versus *space* (as an interweaving of infrastructures)
– Open to evolving & changing uses or events	– neutrality – flexibility & variability – functional indeterminacy	– *Intermediate(uncoded or weakly coded) spaces*
– Awareness (of people, events, context, etc.)	– specificity – visual (auditory) relations	– *Vista* and *social transverse* as supporting peripheral awareness of people, events and context

Table 1. Relating qualities of social use to spatial qualities

– *Open to evolving and changing uses and events:* Addressing design from within the program of ethnographic research means to look at work as being strongly connected to a ‘context’ and to be interested in the details of how social practice is constituted ‘in the doing’ by practitioners. This perspective confirms and radicalizes our notion of ‘use as event’. It draws attention to a dimension of people’s work, in which they actively, flexibly and reflexively re-form, reorient and recombine their actions to fit the exigencies of the work as it unfolds. On the level of method this corresponds to a notion of design as ‘bricolage’. With respect to systems design bricolage is a metaphor for handling openness and indeterminacy, for “using ready-at-hand materials, combinations of already existing pieces of technology - hardware, software and facilities (e.g. Internet providers) - as well as additional, mostly ‘off-the shelf’ ones” (Wagner *et al.*, 1997). For architectural design and planning it means to use ‘innovative combinations’ of forms and materials for augmenting designers’ capabilities of combining and ‘contradictory combining’, of discovering and inventing, of creating confrontation and harmony.

– *Awareness of events, people and context*: All work is strongly connected to a context - of documents and objects, of people, of an ‘ecology’ of organizations and institutions, of an organizational history and memory. The work is shared among people who move in and out of proximity, are more and less continuously intertwined with one’s work, are harder or easier to reach through different media, are always or alternately recipients or providers of one’s work. This also involves the linking of very heterogeneous materials in different media, and strong interlinkages between physical (e.g. paper-based) and electronic materials. What is needed is therefore not a simple extension of the physical space so that all the actors are always present during all the stages of the design process, but a flexibilization of this space.

2.1 Regions and connections to other places

The need for regions and connections, for places *and* spaces, can be grounded in a variety of case studies.

The case of a radiology department (Fig. 1) illustrates the spatial 'bounding' of cooperative relationships (Tellioglu & Wagner, 1996). The department's physical space is a rectangular area with the diagnosing and reporting room occupying a privileged space in the center. It 'contains' what is considered the highest ranking expertise within radiology, the ability to construct a medical judgment. Close to this area is an open space where radiographers process and distribute the images. They frequently move between this central computer unit and the machine space in which the images are produced. This machine space which houses the different imaging machinery is divided into a series of small rooms which are laid out around the core. When we look at the additional connections created by PACS (the image processing system), HIS (the Hospital Information System), and RIS (the Radiology Information System), these are partial, reflecting (rather than opening up) professional boundaries. Electronic connections between the radiology department and the clinical areas are only one way, and this in both directions. All requests for images are made by clinicians, and radiologists have little influence on the timing, the number and the nature of these requests. On the other hand, radiologists do not share their images with clinicians unless being explicitly asked to.

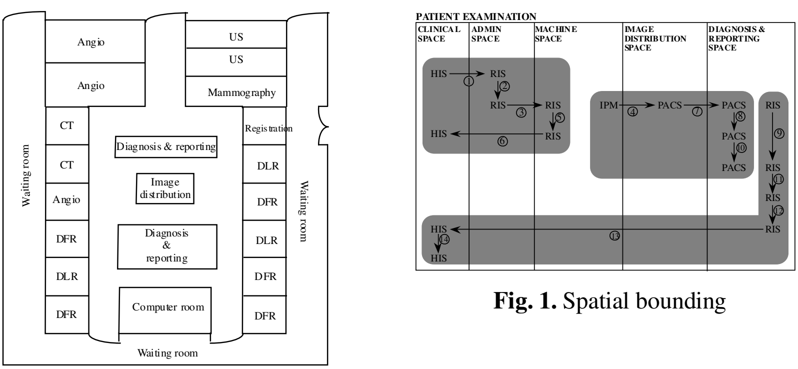


Fig. 1. Spatial bounding

Here spatial separation and a lack of connectivity make the formation of multidisciplinary dialogue around the production of radiological images and reports difficult. This leads to a more general point, which is connected to a feminist notion of place. While being 'homed' in a place provides people with a particular kind of agency (including the power to write their own narrative, respectively to 'dictate' the stories of others), having to act from another place may restrict this ability.

The case of a small local office of landscape designers which is part of a large international company illustrates this point (Shapiro *et al.*, 1997). Lotus Notes was set up by the company's marketing and quality assurance department as a shared electronic space for documenting and reporting. The central office's notion of how to design such a space did not include the possibility to define 'regions', and hence to reserve some information for use on the local level only. Also, as data replication was done centrally, people on the local level could never be sure about the status of their own data, if e.g. someone else had changed or removed some locally relevant information (Wagner & Tellioglu, 1997).

In this electronic space local 'authors' can no longer write and control their own scripts and heterogeneity cannot be made visible.

This discussion also suggests to distinguish between place and space. While *place* focuses on the groundedness of what and how it is done in a particular context of people, environment, history, etc., emphasizing the specific contextuality, situatedness of social action and the needs for boundaries, *space* contains and structures activities in ways that are embedded in and interwoven with other parts of the environment. From this perspective space can be seen as an interweaving of infrastructures (Star & Ruhleder, 1996).

The Lotus Notes example also shows that, instead of 'de-regionalizing' space, it may be more adequate to create or preserve local places while at the same time providing connections. The physical connections between places and spaces can be of a very different quality and nature. They might take the form of fluent transitions between inside and outside (including the possibility to e.g. convert an inside space into an outside space), or of direct and fast access to places. One can also be connected on a more symbolic level, with the design of a place reflecting other places.

We are interested in connections that "escape or subvert standardization, that are between the categories, yet in relationship with them" (Star 1991, p. 39). These kinds of connections might be created by inventing new and alternative kinds of connections or 'innovative combinations' of existing ones.

Fig. 2. Transformation layers

An example of this kind of connections is the skin of a building-in-development, the *Cinema Center*, consisting of a spatial stack of containers. These volumes are wrapped up in an intermediate space, which is bounded by a translucent skin. During the day the building transforms its appearance, shimmering hermetically in the morning, partially reflecting its surroundings. The changing light produces an almost imperceptible metamorphosis. The arrangement supports the configuring of 'cinematic images' - light interventions of different kinds. Projections (e.g. of movie titles) can be used, or light images which change the building's skin. When it gets dark, the lighting of the building's inner space creates a festive character, the façade turns into a veil delicately hiding people and movements.

A building's multiple façades can be seen as a '*transformation layer*' which mediates between interior and exterior spaces, and this in different ways. The 'skin' facilitates changing relationships between inside and outside. The building can communicate its contents. Depending on the daylight, these connections are one-way or reciprocal. Their specific quality derives from their degree of transparency, opaqueness and compactness.

2.2 Open to evolving and changing uses and events

This openness can be achieved in different ways. One is connected to the distinction between *neutrality* and *specificity*. A place can be designed in ways that are relatively neutral with respect to the activities for which it provides a space, without being disruptive of conventional connotations; or it can be specifically expressive, communicating particular notions of community, life style, particular times, artifacts and places.

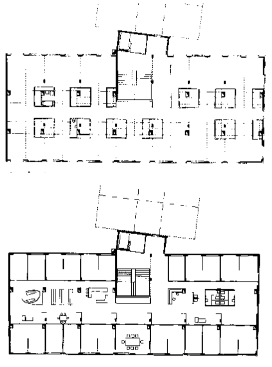


Fig. 3. Neutral structure - flexible uses

Within architectural discourse, openness to varying social uses is also connected to the traditional distinction between *flexibility* and *variability* as generic properties of a design. Flexibility connotes the possibility of relatively simple changes to a design so as to adapt it to different or shifting social uses (e.g. moveable walls). Variability means that a designed space or artifact, without elaborate transformations, can accommodate a variety of functions (e.g. a container, which can be filled in).

The ‘Health Centre’ project is an example of a neutral’grid’ which can be adapted to different social uses (from different types of medical examination and therapy to office space and temporary lodging) by combining and eliminating and spatial elements.

An approach to accommodating to the evolving and changing nature of social use is the concept of intermediate (uncoded) space. It is this quality of being located ‘between’ more univocally coded spaces for distinct uses (or functions), which makes such spaces open for multiple interpretations and uses.

An *intermediate space* may reflect the surrounding spaces, or paraphrase them in a way that suspends clear categorizations. These are spaces which facilitate the joining of not only multiple meanings, but of multiple forms and formats, of coded and uncoded notions of space and social use, inviting people to practice their own definitions. They may be used as a transitory space, a niche for peripheral activities or some temporary concern; provide boundaries, thresholds, openings and transitions. Within a school building, for example, spaces are narrowly coded. This is reflected in a dense regulatory framework, which fixes many parameters (e.g. defining the prototypal classroom). Here designing *intermediate spaces* opens up opportunities for ‘parasitic appropriations’, such as spontaneously organized activities, interdisciplinary events and other boundary crossings.

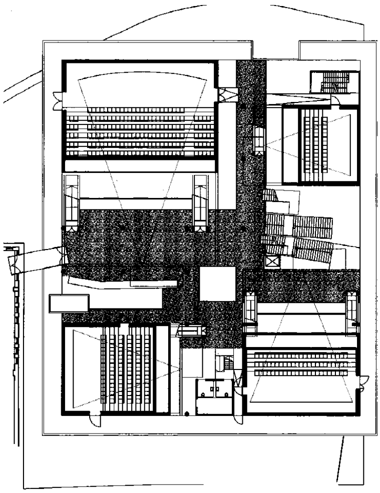


Fig. 4. Intermediate spaces

A related approach is Bernard Tschumi's notion of „spaces of movement corridors, staircases, ramps, passages, thresholds … . Bodies not only move in but generate spaces produced by and through the movements“ (1980, in Nesbitt 1996, p. 154). These spaces of movement are both, defined by their 'obvious' function as spaces for moving in between (rooms, floors, inside & outside), and therefore intermediate (eventually inviting to sit down and chat, being converted into a temporary place for eating, reading, storing, etc.).

Central to the design of the *Cinema Center* are spaces of movement which can be looked at as *intermediate spaces*, providing opportunities for spontaneous encounters and temporary installations. Protected niches alternate with open, 'public' spaces.

Openness may also be achieved through a combination of spatial specificity and functional indeterminacy.

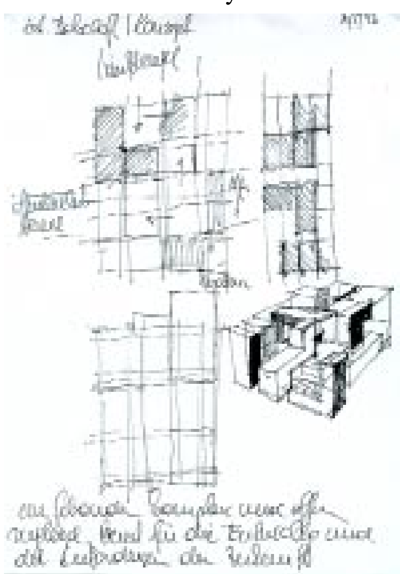


Fig. 5. Functional indeterminacy

The *Embassy Project* exemplifies this approach. The object has been conceptualized as an open system of volumes and voids, which form a set of fixed spatial elements. Openness is created by the interplay between spatial configuration and functional program and the ambiguity of their relation. It is not so clear where specific functions could or should be 'placed' and activities be located. The design forms a container which, although not neutral, can be filled in, is open to a variety of possible uses.

The allocation of functions or uses is malleable, they are fitted into the spatial configuration. While some of them find ample space, others might have to be squeezed in, overlap, extend into neighbouring spaces, thereby creating 'natural' connections or meeting 'fixed' boundaries. This not only allows to suspend or transgress the usual hierarchy of functions and rooms. Also, the boundaries between interior and exterior space are designed as permeable and fluent.

Variability of use of *intermediate spaces* can be achieved by providing different kinds of *implantations*. These are objects or devices, which support the customizing of a space to changing uses.

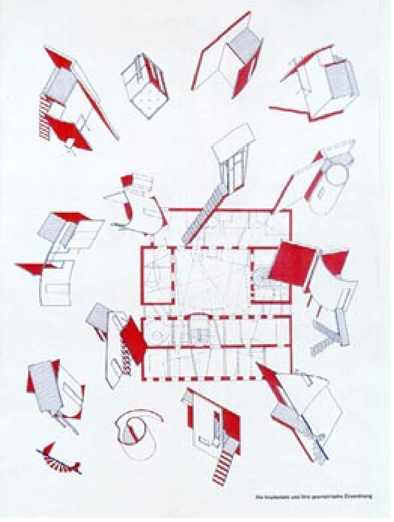


Fig. 6. Implantations

Implantations may take the form of special equipment or furniture needed to carry out specific activities. They may be used for creating spatial partitions or for imprinting specifically expressive codes.

Implantations in the 'Embassy Project' consist of a set of elements for creating vertical and horizontal connections and transitions, such as intermediate horizontal partitionings, ramps, ladders. While the positions of some of these elements might be already fixed (e.g. where people can stand outside they also should be able to move inside), others can be held open and adjusted to variable social uses.

2.3 Awareness

Awareness of people, events, and context is another particular quality of use to be accounted for in the design of space. Context is closely related to our notion of specificity. A space can be designed to reflect important aspects of context, such as the surrounding environment, the history, the particular activities that take place in it, etc. Here we seek to specify context in relation to a notion of 'awareness'.

Being co-located enables people to create and maintain the kind of 'peripheral awareness' which within CSCW research has been identified as a crucial element of cooperative work. People often take an active part in supporting mutual awareness by making aspects of their activities visible.

The architectural correlate of this is an *exhibition space* – a dedicated area (such as a wall, a whole room) which invites and allows the display of events and objects. A special feature of architects' own work environment is its use as *exhibition space*. The walls are decorated with visualizations from previous and current work – models, sketches, plans, texts, pictures, (photorealistic) computer images. This way of making work visible reminds of ideas to be pursued or further developed, of tasks to accomplish, of standards, etc. It also is an important vehicle for peripheral participation in a project, allowing visitors to enter its context. Conversations are opened up, designers are forced to explain to continuously changing interactors. They can create and communicate their identity without closing it too much. (Wagner *et al.*, 1997).

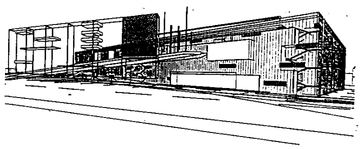


Fig. 7. The 'Developing Wall'

The 'Developing Wall' (Project 'Austria Email') has been conceived as a changeable exhibition space. Central to it is its 'incompleteness'. It can be used for communicating different contents, from an art collection to exhibits of the company's products. It may serve as an open research lab or studio, provide space for relaxation.

Awareness of the context of people and events can also be achieved and maintained through visual relations. Visual relations can take different forms and qualities. They can be direct and close, allowing ongoing intimate contact between people who are co-located. Her we refer to the notion of *vistas*, views of or points of reference to other (distant) places. This is a major concern in urban planning.

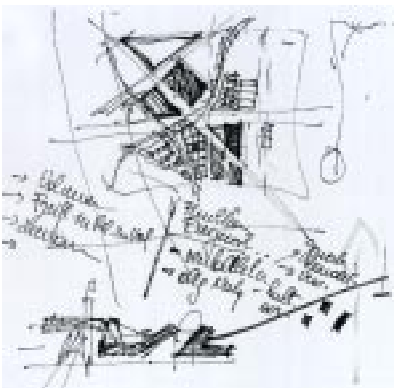


Fig. 8. Constructing a relational field

A design approach (which was explored within several urban planning projects, among them the project 'Altes Flugfeld Aspern') is to start out from the notion of a layered landscape or urbanscape, rather than an already structured conglomerate of buildings and façades. This requires to take account of what is already there - buildings, streets, highways, a river (or memories of them). Taking these as a starting point, a set of visual relations (represented by lines - what to see from where) is defined. The idea here is to create vistas and openings from different places to particular points or places outside (and a particular silhouette seen from a distance). From these visual relations and solid lines a 'grid' is constructed - a 'relational field' of a specific quality (e.g. dense, labyrinthine). This grid can be filled with places of different qualities. Also here the idea is to emphasize volumes rather than objects, distinguishing enclosed areas from free (not enclosed but connected) areas and empty spaces.

Related to this is the notion of *social transverse*, a line along which (social) life visibly takes place, with people moving, eating out, gathering, shopping, etc. Social uses and events are clustered and distributed along this transverse. They happen within sight of each other, are located within a short walking distance, etc. Although independent of each other they are spatially (and visually) connected.

In the EuraLille project Rem Koolhaas (1994) describes a similar approach. Here architectural islands of high density are placed within stretches of emptiness, landscape, or space. Zones filled with massive buildings alternate with large areas of 'urban void'.

3 Merging the Perspectives of Architecture and Systems Design

Some of our ideas of how to support work that is socially organized, embedded in context, flexible, and informal are currently explored and further developed within the framework of several architectural and systems design projects in support of architectural practice.

Some of this work is based on the metaphor of 'Wunderkammer', a 3D multimedia environment for assembling 'inspirational' objects, contexts and metaphors. 'Die Wunderkammer' is not an archiving system but a place for discoveries. Its main purpose is to help preserve and tap the kinds of uncoded and tacit knowledge that is not always easily remembered but may help to better grasp a concept and/or to externalize images that are still difficult to express, and to share them with others (Lainer & Wagner, 1997).

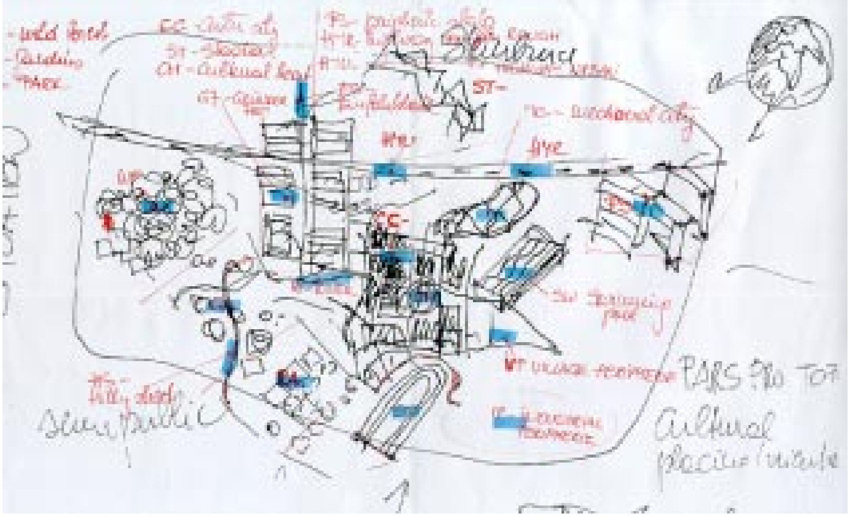


Fig. 9. Die Wunderkammer - places & spaces

The interface of 'Die Wunderkammer' will be an urbanscape (or landscape), where serendipitous encounters can take place and can be captured as inputs to design. Apart from its practical purpose to widen access to 'inspirational resources', we see 'Die Wunderkammer' as an opportunity for further exploring and testing the relationships between spatial qualities and qualities of social use.

As a metaphor guiding the design of electronic spaces, urban space stands for the possibility of providing intuitive access to heterogeneous resources. An urban space offers a mixture of place and space, specificity and neutrality. While some of the places we find there will be relatively neutral and therefore open to a variety of implantations, others will have specific qualities. The interface of our first prototype consists of places of different qualities, appearance and attractivity. Some of these places represent archetypal images of large cities or of areas within them (the urban sprawl, apartment blocks from the 70's, etc.), others places of rest and contemplation (gardens and forests), again others are diffuse, hazy, changeable, thereby potentially blurring, skewing or twisting the images that have been deposited (e.g. water places). Some spaces have this intermediate quality, escaping categorization. Their attractivity derives from being situated 'in-between' or close to a specific place (but not identical with it).

Places of high density alternate with voids (placelessness) and spaces of movement (e.g. a highway). Some places will be more ‘communicative’ than others, more open or closed (e.g. easier to access, protected).

Fig. 10. Inspirational objects

A way of maintaining this space open to evolving and changing uses is to experiment with weak forms of indexing. Here we try to find a solution to the problem that current archiving techniques are insufficient. They require structures that are not dynamic. Archiving happens in a frozen form. In ‘Die Wunderkammer’ indexing will be done by ‘placing’ and objects will assume the qualities of the places in which they have been stored. Indexing items by ‘placing’ means to take advantage of the specificity and ambiguity of place and of the ‘in-between’ qualities of *intermediate spaces.*

We think of providing different modes of access. While sightseers will look for global landmarks (which are historically defined and can be easily identified by an experienced traveler), archeologists will have an interest in the more local (and eventually less ‘telling’ less obviously ‘communicative’) places. They will start digging deeper, revealing different layers, unexpected objects or fragments of objects. The flaneur takes in images and information wherever they happen to capture his/her imagination, engaging in ‘en passant’ conversation, collecting items, taking pictures.

Also, different modes of movement in this 3D-environment will be explored. One of the metaphors with which we describe modes of access to this space is the train ride. It stands for a flow of random, transient impressions that pass by, also for the unconcentrated look of the (tired) traveler whose gaze his caught by an image. When you approach (because e.g. a glimpse of something attracts you or you feel like ‘landing’ in a particular place), the images become more clearly visible.

4 Conclusions

In our paper we use some central insights of CSCW research into cooperative work for looking at places and spaces in a different way. As part of this we introduce a specific vocabulary for talking about cooperation in architectural terms: transformation layer, intermediate space, vista and social transverse. Although these notions are drawn from and illustrated by different design projects, we conceive of them as formative on a conceptual level rather than as formally designed objects.

Many objects (as part of built spaces) can be looked at and used as *transformation layers*. Crucial is the idea of providing (spatial) connections of variable quality that mediate between people and the places they inhabit. Similarly, the notion of *intermediate space* stresses the adaptability of spaces to temporary or unforeseen uses. *Vista* and *social transverse* denote the need for maintaining peripheral awareness of people, events and context, and for enabling casual encounters. Supporting cooperative practice, we argue, simultaneously requires to respect people's need for places and boundaries *and* to enable boundary crossings and adaptations.

Social use is conceptualized as contextual (and as therefore requiring awareness and connections), and 'situated' (something which may change temporarily or evolve in time). Looking at *use-as-event* helps expand the usability and actual uses of space (without necessarily disrupting habitual ways of thinking, archiving, inhabiting, or connecting).

Although such an approach does not offer a specific solution to how to design 'cooperative buildings', it has some important methodological implications. We propose to think of architectural design as creating *spaces in waiting* (Räume in Erwartung) for different and evolving social uses to be filled in. This requires to build opnenness into the design process itself.

Fig.11. Oscillating between 'fixed' and 'open'

At the core of this 'open planning' approach is an idea of decision-making as allowing for shifts between prescription and description, in an artful and fluid manner. We refer to this as 'meandering' which means that it should be possible to go back to an earlier stage of a project, mobilizing images, associations and solutions that 'lay in waiting'. This may not only require to maintain things at different stages of incompletion. 'Meandering' asks for a conceptual shift from working with 'fixed elements' or solutions to working with 'place-holders' and to look at specifications as partial and preliminary. It puts emphasis on the dynamic of opening and expanding, fixing and constraining, re-opening, etc. (Lainer *et al.*, 1997)

Another element of this approach is to engage in richer and more open forms of communication. Open planning needs to work with 'rich narratives', design representations that narrate and evoke imaginations (rather than prescribe), communicate 'qualities', and present a 'solution space' (rather than a set of fixed solutions).

With this combinatory approach of an 'open planning' methodology with a different way of looking at the qualities of designed and built spaces we try to accommodate design practice to the (variable) needs of cooperative ensembles. 'Spaces in waiting' from this perspective reflect the need of people to find a place for and to experiment with open and evolving forms of use.

References

1. Blomberg, J., et al.: Ethnographic Field Methods and the Relation to Design. In: *Participatory Design: Principles and Practices*, Schuler, D., Namioka, A. (Eds.). Erlbaum, Hillsdale, N.J. (1993) 123-156
2. Clement, A., Wagner, I.: Fragmented Exchange. Disarticulation and the Need for Regionalized Communication Spaces. In: *Fourth European Conference on Computer-Supported Cooperative Work,* Marmolin, H., Sundblad, Y., Schmidt, K. (Eds.). Stockholm, Kluwer (1995) 33-94.
3. Gregory, D.: *Geographical Imaginations*. Cambridge MA, Blackwell (1994)
4. Harvey, D.: Between Space and Time: Reflections on the Geographical Imagination. *Annals of the Association of American Geographers* 80 (1990) 418-434
5. Jordan, B.: Ethnographic Workplace Studies and CSCW. In: *The Design of CSCW & Groupware Systems*, Shapiro, D., Tauber, M., Traunmüller, R. (Eds.). Elsevier, Amsterdam (1995)
6. Kompast, M., Wagner, I.: Telework. Managing Spatial, Temporal and Cultural Boundaries. In: *New International Perspectives on Telework: From Telecommuting to the Virtual Organisation*., Jackson, P., v.d. Wielen, J. (Eds.). Routledge Kegan, London (1997)
7. Koolhaas, R.: Toward the Contemporary City. *Design Book Review* (Winter) 17 (1989) 15-16
8. Lainer, R., Wagner, I.: Vienna Architecture Scenario. *DESARTE First Phase Project Overview*, Wagner, I. (Ed.). Technische Universität, Wien (1997) 91-124
9. Nesbitt, K.: Theorizing a New Agenda for Architecture. An Anthology of Architectural Theory 1965-1995. New York, Princeton Architectural Press (1996)
10. Probyn, E.: Travels in the Postmodern: Making Sense of the Local. In*: Feminism/Postmodernism*, Nicolson, L.J. (Ed.). Routledge, New York (1990) 176-189
11. Shapiro, D., Mogensen, P., Büscher, M.: Lancaster Landscape Architecture Design Scenarios. *DESARTE First Phase Final Report*., Wagner, I. (Ed.). Technische Universität Wien, Wien (1997) 37-56
12. Star, S.L., Ruhleder, K.: Steps toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research* (1997)
13. Tschumi, B.: The Pleasure of Architecture. *Architectural Design* 47(3) (1977) 214-218
14. Tschumi, B.: Architecture and Limits II. *ArtForum* 19(7) (1981) 45
15. Wagner, I.: Hard Times. The Politics of Women's Work in Computerized Environments. *The European Journal of Women's Studies* 2 (1995) 295-324
16. Wagner, I. (Ed.,): *DESARTE First Phase Final Report*. Technische Universität, Wien (1997)
17. Lainer, R., Wagner, I., Tellioglu, H.: Flexible Standardisierung. Möglichkeiten der computerunterstützten Integration von Design und Produktion am Beispiel Architektur. Forschungsarbeiten der Abteilung für CSCW am Institut für Gestaltungs- und Wirkungsforschung der TU Wien No 7, Wien (1997).

Law Enforcement of Working Space Requirements in Office Buildings
— The Policy of the Labour Inspectorate in the Netherlands

Rob H. Hagen

Ministerie van Sociale Zaken en Werkgelegenheid
Directie Arbeidsomstandigheden, Postbus 90801
NL-2509 LV Den Haag, The Netherlands
Email: r.h.hagen@minszw.nl

Abstract. As far as quality of work environment is concerned, working space (in terms of floor surface) appears to be an important measure. This relates to: restrictions of mobility, violation of privacy, injury hazards, escape routes and flexibility. The Dutch work environment legislation refers to the application of a national standard. Some Dutch companies use flexible work organization models, where workstation sizes do not meet the requirements in the standard (sometimes 40 % below the required minimum). In 1997 the Labour Inspectorate decided to allow previously selected organizations (about five to ten) to test their concepts in practice. A contract underlines a mutual agreement, inwhich conditions are stated about magnitude, duration, reversability and employees' participation. The Labour Inspectorate demands, however, that these organizations conduct research on usability and work environment issues. This procedure enables companies to innovate in office layout models, while the authorities have the opportunity to adapt the current standards to future experiences.

Keywords. flexible work, organization models, law enforcement, ergonomics, standards, requirement, Labour Inspectorate, human factors

1 Introduction

As far as quality of work environment is concerned, working space (in terms of floor surface) appears to be an important measure. This relates to: restrictions of mobility, violation of privacy, injury hazards, escape routes and flexibility. A small workstation, (from an ergonomics point of view) does not have to be a problem on itself. Health hazards more likely occur as a consequence of factors deriving from restricted workstation sizes. For example climate, ventilation, lighting and daylight conditions.

2 Legislation

The relevant legislation in the Netherlands, the Work Environment Decree, prescribes the requirements only in general wordings: sizes and air volume of workstations need to guarantee a safe and health environment and appropriate mobility. The legislation refers to the application of a Dutch standard. By definition a basic workstation - is a workstation that consists of an office chair and table, a mobile pedestal, a VDU-work layout and a filing cabinet. The standard indicates that a basic workstation requires 8 m^2 of floor surface. An additional m^2 should be available for the entrance of any office area.

Thus an office area for one employee is at least 9 m^2. Two employees: 17 m^2. Three employees: 25 m^2, etecetera. In case any extra furniture is needed, for example a filing cabinet or a desk for consultancy, a fixed number of square metres will be added to obtain the required minimum size area. The sizes are valid in any office area where VDU-work takes place. To apply the standard, the workstations generally have to be in use for at least two hours a day or once a week an entire day.

The difference between law and standard is very important. In this case the legislation refers to the application of a standard. If an office area comforms to that particular standard, it ensures that the legal requirements for workstation size are met. On the other hand, the law does not necessarily require comformity to that standard. In this case, however, the employer is obliged to demonstrate that ergonomic principles are appropriately taken into account.

3 Flexible Work Organization Models

Inspired by Scandinavian combi concepts developed in the eighties, some Dutch companies (for example: banks, insurance companies and public services) use flexible work organization models. The main features of these models are:

- collective facilities for the benefit of communication and support
- seperate small-scale office units, where workrooms are situated around a central concourse
- individual workrooms permitting concentrated work
- collective workrooms for two or more employees

In these models, employees do not have fixed workstations. They are able to decide each (part of the) day, to work alone or with one or more collegues in the same office area. From a facility management point of view, the total capacity of the office building may be lower than in a traditional concept with fixed workstations. In this way companies manage to increase the average effective occupation rate, reducing the accommodation expenses. In practice workstation sizes in some of those organization models do not meet the requirements in the previously mentioned standard (sometimes 40 % below the required minimum). But should this be a sound reason to disapprove these flexible work organization models?

4 Law Enforcement

The Labour Inspectorate, in charge of law enforcement of work environment legislation, is generally engaged in a rather late stage of redesign processes. As a consequence, decisions of the Labour Inspectorate may have a gross impact on the building process in particular cases as well as on a national scale. The widespread use, nowadays, of flexible work organization models enforced the Labour Inspectorate to develop a policy regards these companies. In short, the policy implied that previously selected organizations (about five to ten) were enabled to test their concepts in practice. In other words: flexible work organization models got the benefit of the doubt to prove that they result in a situation, which guarantees equal quality in terms of satisfaction and usability, compared with traditional concepts where work environment standards have been implemented. Above all, the standard is based on traditional, fixed workstations.

For such an experiment an agreement has to be made with the company concerned. In that case both the Labour Inspectorate and the company need to agree on:

- magnitude of the experiment
- duration of the experiment
- reversability
- employees' participation

Above all, the Labour Inspectorate demands that these organizations conduct research on usability and work environment issues, especially focused on three categories.

1. satisfaction/complaints

- complaints of back- and headaches
- complaints of pain in upper extremities and neck
- satisfaction of information technology
- satisfaction of filing opportunities
- appreciation of privacy

2. usability

- occupation rate of office area
- occupation rate of single workrooms
- productivity

3. workstation layout

- quality workstation layout
- climate

- daylight
- noise
- hygiene

This procedure enables companies to continue with their innovation process. On the other hand, the involvement of the Labour Inspectorate offers the opportunity to evaluate success and failure factors of flexible work organization models. In this way, authorities like the Labour Inspectorate, have the opportunity to adapt the current standards to future experiences. And that, of course, will be in favor of the development of future work environment policy.

Organizing Space in Time
— Discovering Existing Resources

Karin Joeckle, Monika Schneiders, Thomas Sieverts

Technical University of Darmstadt, Department for Architecture
El-Lissitzky-Str. 1, Darmstadt D-64287, Germany

Marianne Koch, Hartmut Chodura

Fraunhofer Institute for Computer Graphics
Rundeturmstraße 6, Darmstadt D-64283, Germany
Email: [koch, chodura]@igd.fhg.de

Abstract. Flexible societies require flexible environments. Due to economical, ecological and social reasons it can be more efficient taking advantage of existing architecture rather than creating new buildings.

A Web based information system is proposed which can support the distribution of information for 'temporal available space' for providers and users. Potential providers are able to store their space information via Internet. While users can request information about required locations.

Examinations made in an eastern Berlin district have shown that information based management for space and time is improving the efficiency of using existing environment. Furthermore schools, garages, shops and unused facilities can become attractive locations for social events.

Keywords. spatio-temporal management, reusing existing environment, density of usage, social events, hotelling, pool for rooms and buildings, electronic information system, World Wide Web, flexible workplace management

1 Motivation

The flexibilization and pluralization of today's society and working structures also requires dynamic occupation and usage of rooms, buildings and facilities. Hence existing space has to be available for multiple purposes and different users. In middle Europe most urban structures like factories, office buildings, shops or public institutions are only temporarily used. Statistically, the amount of newly constructed space for every German citizen is 150 m^3 in comparison to 10 m^3 at the beginning of the industrialization. As Moewes (1995) pointed out, this has led into a more extensive utilization of built environment. An alternative for planning and constructing more buildings should be opening up this unused space. The generation grown up after the second world war remembers using the few not destroyed schools in time shifts. Additionally using and reusing already existing space is more ecological and economical. Beyond these rational reasons: by using and visiting a larger variety of buildings and sites it opens the chance to learn more about one's city. Especially in centers of urban areas, most of the buildings are occupied by anonymous functions. Making space available for other purposes which presently is mostly unused and inaccessible would allow the citizens to identify with their city (Fig. 1). This is also demanding a new way of organizing spatio-temporal requirements. It would also enhance the liveliness and social density of the city for a longer time of the day and week.

Fig. 1. Discovering existing resources by organizing space in time.

2 Managing Space and Time

An example for existing spatio-temporal management is the "Bleyenburg", the former "Algemeen Rijksarchief" in The Hague, Netherlands. As Teunissen (1997) described, nowadays the building provides on-demand workplaces for civil servants. Beyond the concept of "hotelling", as explained by Jaunzens (1997), the building does not offer complete workplaces but a basically unrestricted supply of components at cost. By these elements (space, technology, furniture and services) the users create their own surroundings for work. With an average occupation time of 60 percent, the price-conscious user of the "Bleyenburg" has a reliable workplace for the equivalent of 130 DM per week in the center of The Hague at his disposal, which is a real bargain.

Another example of flexible workplace management is "hot-desking", as shown at Andersen Consulting's new headquarters in Paris. Jaunzens (1997) describes hot desking as the time-sharing of a desk, or workstation, between a number of company employees. Like in many other organizations and institutions Andersen's employees were found to be spending much of their work time at their clients sites while their in-house offices were unused for most of the time. It now offers a limited but sufficient capacity of on-demand offices. Personal documents of the employees are stored in special containers, which are moved to the appropriate offices if necessary.

These two examples of flexible space-and-time-management is the common way of applying it. It can only be of advantage to a special group of users. But this principle can and should also be transferred for the benefit of a more general clientele (Fig. 1). It can be adapted to many types of buildings which are only used on temporary basis like offices or public facilities.

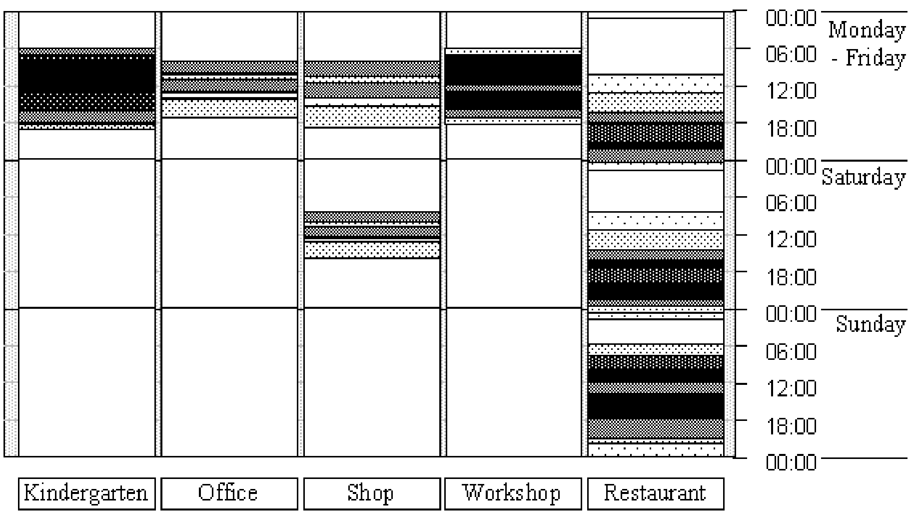


Fig. 2. DOUs of five different types of buildings.

One of the conditions for such an adaptation is the temporal analysis of the site.

The DOU (density of utilization) for a building can be described as a function in time where the value of zero means the room is unused and the value of one means it is completely occupied. The density, which represents the utilization of space is specified as a percentage of the maximum exploitation. Hence the DOU is the unit of measurement for the utilization of an area at a corresponding time.

Fig. 2 shows the DOU of a kindergarten, a bureau, a store, a workshop like a garage compared to the DOU of a restaurant. The DOU is represented by different gray tones. The darker the gray tone, the more intensive the utilization. The white areas represent the temporal fallow of each building. The weekdays Monday to Friday are summarized in one field to make the graphics clearer.

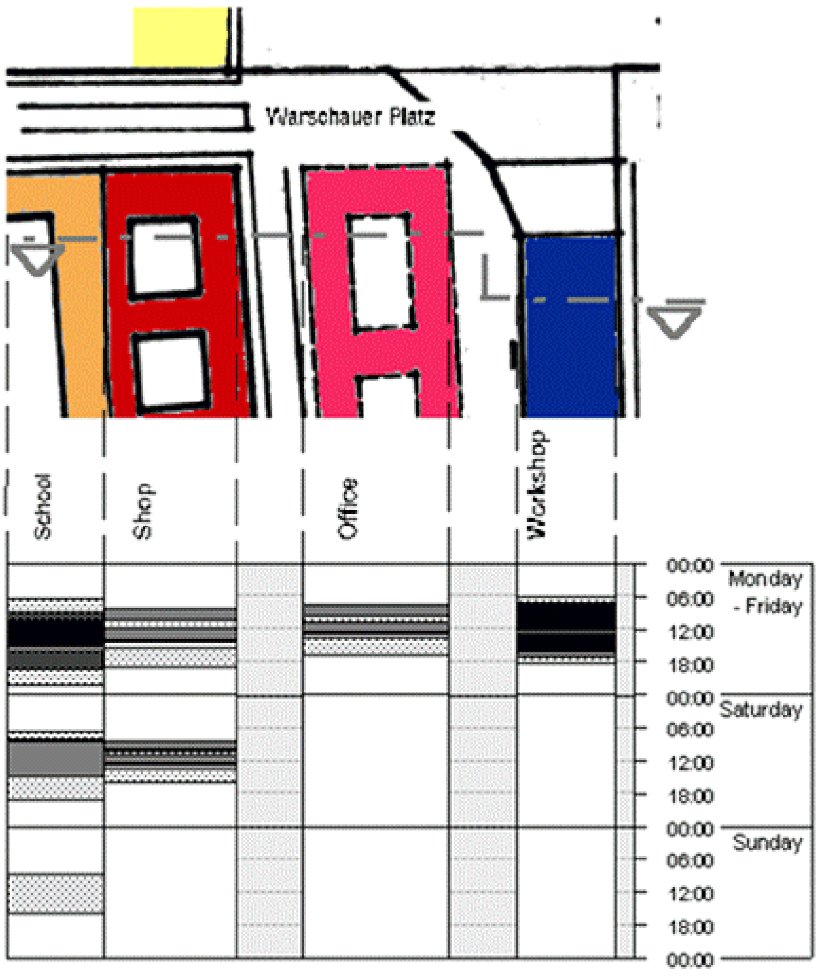


Fig. 3. DOUs at Warschauer Platz in Berlin Friedrichshain.

The authors were exploring and analyzing a region in Friedrichshain, eastern Berlin with a typical urban environment of residential and commercial areas together with the site of the former NARVA Company which used to produce incandescent lamps from 1909 to 1995. Today the buildings are changed into an office monostructure. In their study Habermann/Joeckle/Schneiders (1997) have disclosed the temporal fallow of the area and the possibilities of additional use (Fig. 3).

The strategies of spatio-temporal management include considerations on sociological aspects of possible usage, specific user-groups and their changing needs as well as organizational and legal considerations of conceivable developers and forms of development, problems of insurance and liability, technical questions of construction and facilities, as Häußermann/Siebel (1987) have elaborated.

Professional management of space and time requires an analysis and representation of time-realities of an area. An information system should provide all relevant information for interested persons, about what kind of room is available and what additional use is possible or intended.

3 Getting Information about Available Space

In order to achieve an optimum for the distribution of unused space in urban environments the problem of information access has to be solved. Only if both supply and demand for usable space are sufficient the concept will be feasible. There are similarities to car pool services, which also need a certain level of demand and supply to succeed.

3.1 Making information accessible for everybody

We are currently experiencing a new era of information distribution and retrieval. For most people in western societies only small expense and effort is necessary to be able to get "wired" to the globally accessible Internet. Here everybody can be both author and consumer for multimedia information.

Together with the "World Wide Web" there is a big variety of standards for data transmission and storage, accessible from any location which is connected. As Encarnação *et al.* (1996) have shown, there are new tools like JAVA and three-dimensional graphics offered by VRML which are enhancing the interactivity and functionality of hyper media.

Strongly related to this there is an important social consequence. For instance in middle Europe the fraction of people who have access to the Internet are still a minority of the population. However, a possible polarization of society into the privileged party with access to the global information systems and the underprivileged with no or little access to these system may arise.

Nevertheless we attempted to use an electronic information system for organizing space in time. The global trend is that the amount of "wired" households is still growing tremendously. More importantly, there is no need for private Internet and

WWW access for everybody if, there are enough public accessible information kiosks, like "Internet Cafes".

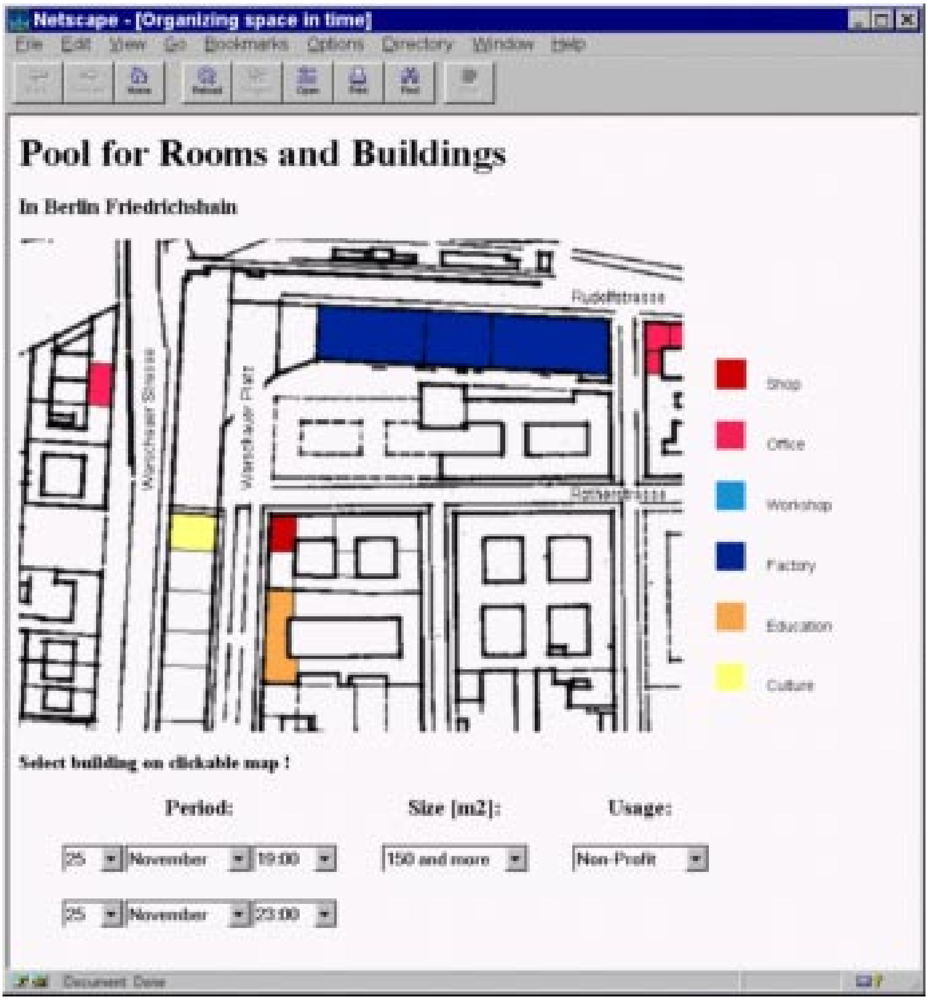


Fig. 4. Possible user interface for the information database. The users are able to find a convenient location by selecting buildings on an active map.

3.2 Information based space and time organization

We propose a, WWW based approach for public access to necessary information, accessible by both users and providers. The information can be managed by 'connected' Internet users running their Web-Browser. In many regions and areas it will be necessary to enhance electronic information structure by information kiosks to aim at as many users as possible. There are numerous public locations in centers of urban regions and metropolitan areas where people pass by and socialize, such as stations, cafes, credit institutes, or tourist information kiosks. These are ideal locations for information systems, which could be used for many purposes.

An information server should cover a region where locations can be reached within convenient time and distance. Bigger areas could be supported by a net of information servers. Graphical WWW-interfaces for accessing the database can provide user-friendly access to the database.

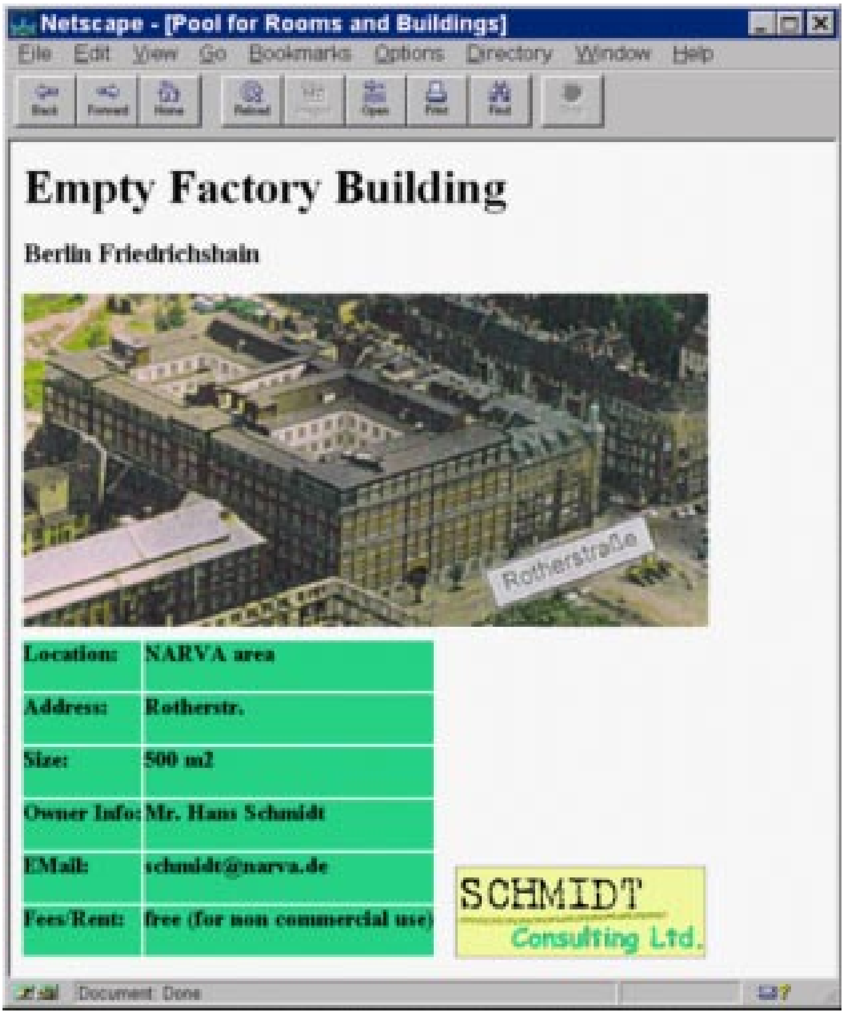


Fig. 5. Detailed information about empty buildings can be accessed. Commercial providers are able to advertise their business.

The following information have to be stored in the database:

– Locations
  For having a good overview over the area where the buildings are located, clickable maps will allow easy access. (Fig. 4)
– Size, capacities and facilities
  There has to be information about how many people will fit in an offered room or building and which local facilities could be used. Garages i.e. could sub-rent their tools and equipment for fees, which allows skilled people to repair their cars after work.
– Schedule of occupation
  It is necessary to have an immediate overview at which time and period the offered buildings are accessible or if they are already occupied by someone else.
– Owner / provider information
– Preconditions and constraints
  There has to be some principle information about the offered location. Not every room is suitable for parties or rehearsal of musicians.
– Using fees or rent
– Space for advertisement
  Commercial providers could be able to add advertisement information to the web-pages. If this could be arranged on a toll-free base it would attract more potential customers. (Fig. 5)

3.3 Technical realization

The technical structure of the proposed information system is shown in Fig. 6. The implementation will be Web based using conventional browsers. The information of the provided space will be stored in a database which is accessible by a WWW server.

The population of the library has to be realized by a Web interface as well. Initially this could be attempted manually (by a webmaster) which makes the implementation easier but does not provide the full flexibility we like to achieve.

Dependent on the offer for empty rooms users will get a visualization of the area which is shown in Fig. 4. For realizing this functionality we will develop a JAVA based interface which allows to:

– generate clickable maps with the necessary information dynamically,
– request more detailed information about empty rooms or buildings like shown in Fig. 5,
– make a reservation for accessible space or get into contact with the providers to arrange a possible booking.

This interface, implemented as a JAVA applet allows processing in common Web browsers and provides sufficient freedom for integrating more complex algorithms and extended functionality to the static HTML resources.

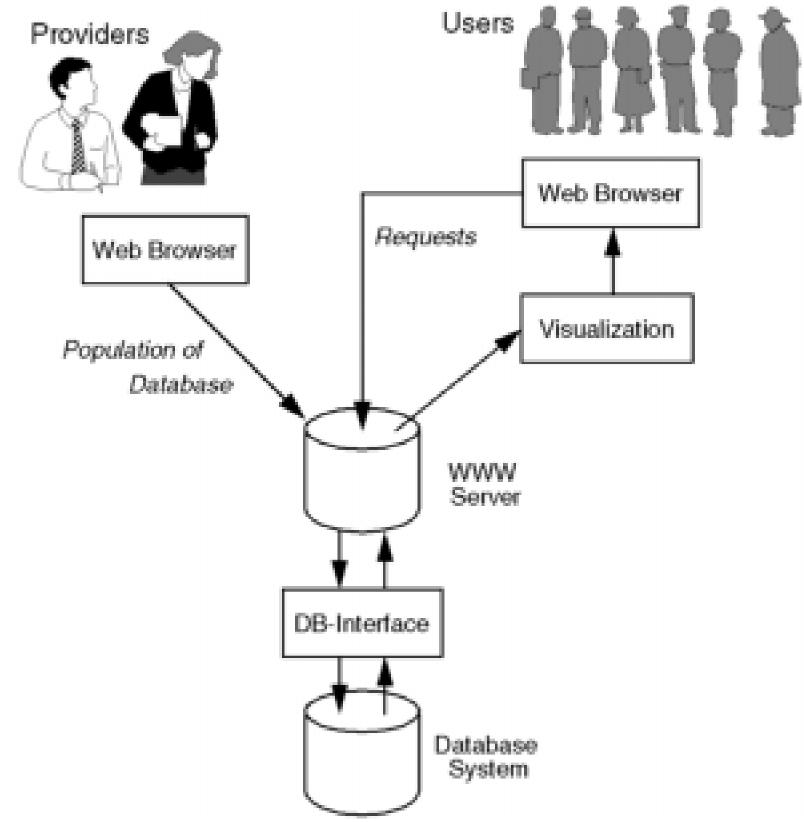


Fig. 6. Structure of the management system for space and time

4 Conclusion

We have proposed an information resource for managing unused space in already existing urban areas. This information resource can be used to satisfy demands for temporary occupied buildings and facilities which can be used in multiple ways. By analyzing typical urban regions multiple ways can be found for optimizing the usage of rooms and buildings for various purposes.

Based on the analysis of a real existing environment in Berlin it has been shown that unused space can be transformed into interesting places. Furthermore areas which are unknown to most inhabitants of a city can change into lively locations. This turns them into new points of interest and stimulates social activities.

This concept can be applied to many existing urban surroundings, yielding economical and ecological advantages.

References

1. Brown, Erik: Watch this space. *Management Today*. (February 1995) 73-74
2. Encarnação, José; Bauer, Klaus M.; Böhm, Klaus; Koop, Tanja; Spierling, Ulrike: New User Interface aspects to the Information Highway. Applying Java and VRML. *International Journal of Information Technology*. (January 1996) 2 (1) (1996) 79-96
3. Häußermann, Hartmut; Walter Siebel: *Neue Urbanität*; Suhrkamp Verlag, Frankfurt am Main (1987)

   "Bei allen Strategien verknüpfen sich sozialwissenschaftliche Überlegungen über mögliche Nutzungen, spezifische Nutzergruppen und deren sich wandelnde Bedürfnisse mit organisatorischen und rechtlichen Überlegungen über denkbare Träger und Trägerformen (weiterhin in der öffentlichen Hand oder kommerziell, selbstverwaltet oder in Individualeigentum?), versicherungs- und haftungsrechtliche Probleme mit technischen Fragen des Um-, Aus- und Rückbaus, schließlich mit raum- und sozialplanerischen Überlegungen." 155.

   [All strategies imply considerations on sociological aspects concerning possible usage, specific user-groups and alternating needs as well as organizational and legal considerations of conceivable developers and forms of development (further under public authorities or commercial, autonomous or private property?), problems of insurance and liability, technical questions of construction and facilities, and finally area and social planning.]
4. Habermann, Julia; Joeckle, Karin; Schneiders, Monika: *Zeit-Raum*. TU Darmstadt (1997)
5. Henckel, Dietrich (Hrsg.); Deutsches Institut für Urbanistik Berlin: *Arbeitszeit, Betriebszeit, Freizeit - Auswirkungen auf die Raumentwicklung. Grundlagen und Tendenzen*; Schriften des Deutschen Instituts für Urbanistik Bd. 80, Verlag W. Kohlhammer / Deutscher Gemeindeverlag Stuttgart (1988)
6. Henckel, Dietrich; Grabow, Busso; Kunert-Schroth, Heidrun; Nopper, Erwin; Rauch, Nizan; Deutsches Institut für Urbanistik Berlin: *Zeitstrukturen und Stadtentwicklung*; Schriften des Deutschen Instituts für Urbanistik Bd. 81, Verlag W. Kohlhammer / Deutscher Gemeindeverlag, Stuttgart, Berlin, Köln (1989)

   "Die Flächenerweiterung ist das bislang übliche Muster des Umgangs mit Engpässen gewesen. In dem Maße, wie Flächen knapp werden oder aus ökologischen Gründen nicht zusätzlich in Anspruch genommen werden sollen, treten Überlegungen von Zeiterweiterungen stärker in den Vordergrund." 189.

   [Up to now expansion of space has been the usual way of coping with bottlenecks. The more space gets scarce or precious because of ecological reasons, the more considerations of time-expansions appear.]
7. Jaunzens, D: New Ways of Working - The Future of Offices and Environmental Services. In: *Proceedings of the COBRA Annual Construction and Building Research Conference 1997*, The Royal Institution of Chartered Surveyors RICS.

   URL: http://www.rics.org.uk/research/cobra97/cobpdf/jaunz.PDF [December 1997]

   "In the office as a hotel it is possible to book office space as one might book a hotel room." 4.
8. Jessen, Johann; Siebel, Walter: *Wohnen und informelle Arbeit*, ILS Schriften Bd.19; Institut für Landes- und Stadtentwicklungsforschung des Landes Nordrhein-Westfalen (1988)

   "Die Verknappung der natürlichen Ressourcen, die wachsende Umweltbelastung und Gesundheitsgefährdung durch Schadstoffe als Folge einer ausschließlich wachstumsorientierten Stadtentwicklung veranlassen aus ökologischer Perspektive Vorschläge für einen ökologischen Stadtumbau." 28.

[From an ecological point of view the shortage of natural resources, the growing environmental pollution and health hazard through pollutants as consequence of an expansion-oriented city development induces suggestions for an ecological city-rebuilding.]

9. Kasugai, Michihiko: Die Zeit als Element der Stadtplanung - dargestellt am Beispiel Japan; TU Darmstadt Diss. (1985)
10. McNamara, E. T. (Terry): Intelligent Buildings: Engineering Services Integration Via Virtual Management Information Systems, In: *Proceedings of the COBRA Annual Construction and Building Research Conference 1997*, The Royal Institution of Chartered Surveyors RICS, URL: http://www.rics.org.uk/research/cobra97/cobpdf/Mcnama.PDF [December 1997]
11. Meurer, Bernd (Hg.): *Die Zukunft des Raumes*. Campus Verlag Frankfurt / New York (1994)

"Nutzungs- und Funktionsmischung ist Voraussetzung für die Entwicklung einer dynamischen und belebten Region mit belebten Städten, Quartieren und baulichen Ensembles. [...] Hinzu kommt, daß gerade für ein Entwicklungsgebiet mit Mangel an Baugrund die Chance, Freiflächen trotz Wachstum zu erhalten und Stadtraum als im Wortsinn lebendigen Interaktionsraum zu entwickeln, in der räumlichen Überlagerung unterschiedlicher Aktions- und Funktionsbereiche liegt. Dafür bedarf es der Entwicklung hybrider Stadt- und Gebäudestrukturen." 27.

[The development of a dynamic and animate region with animate cities, quarters and structural ensembles requires a mixture of usage and function. Moreover, a development area will have the chance to keep open space through spatial interference of different areas of action and function in spite of its growth and lack of building sites. This requires the development of hybrid structures for cities and buildings.]

12. Moewes, Günther: Weder Hütten noch Paläste. Architektur und Ökologie in der Arbeitsgesellschaft, eine Streitschrift. Birkhäuser Basel , Boston, Berlin (1995)

"Das Pro-Kopf-Bauvolumen ist seit der Industrialisierung von etwa 10 auf mindestens 150 m^3 angewachsen. Nimmt man den Bevölkerungsanstieg hinzu, hat sich das Gesamtvolumen absolut mindestens versechzigfacht. Die Nutzung dieses gewaltigen Volumens wird immer extensiver. " 63.

[Since industrialization began the capita volume of built space has grown from 10 to at least 150 m^3. Together with the growth of population the total volume has been multiplied by sixty. The usage of this massive volume is getting more and more extensive.]

13. Sieverts, Thomas: *Zwischenstadt. Zwischen Ort und Welt, Raum und Zeit, Stadt und Land.* Bauwelt Fundamente 118. Vieweg Verlag Braunschweig, Wiesbaden (1997)
14. Teunissen, Rob: Erfolgsrezept Hotelbüro. Das ehemalige Algemeen Rijksarchief in Den Haag. *Bauwelt 1997, Büros auf Zeit* (Mai 1997), 88 (21) (1997) 1196-1199.

"Bei einer durchschnittlichen Anwesenheit von 60 Prozent kann der kostenbewußte Nutzer von Bleyenburg für 130 Mark pro Woche über einen verläßlichen Arbeitsplatz im Zentrum von Den Haag verfügen." 1199.

[When being present for approximately 60 percent, Bleyenburg is offering a reliable workspace in the center of The Hague for DM 130 per week to cost-conscious users.]

A Room Management System

Christian Falkowski

University of Linz, Austria
Telecooperation Department
Altenbergerstr. 69, Linz A-4040, Austria
Email: chris@tk.uni-linz.ac.at

Abstract. Experiences and problems during setting up of actual CSWC - offering working environments have an important impact on the conception of Cooperative Buildings. Infrastructure for CSCW working environments must deal with a set of very inhomogeneous needs, e.g., media and device control, access control, communication capabilities, cooperation aware software etc. For reaching an adequate usability of the advanced functionality, especial for no computer experts, a high integration effort is necessary. The Room Management System (RMS) is a generic tool for observing and controlling activities within a distributed CSCW environment. It groups desktop objects of different users in one view, thus making available central actions on a group of user desktop objects. Additionally it controls the access to media and devices by the different users.

Keywords. room control system, CSCW, user management

1 Motivation

The Conference/Classroom of the Future (CCF) project inside the Ars Electronica Center in Linz described by Mühlhäuser *et al.* (1996) aimed at setting up a learning- and working environment that uses advanced information technology to support co-operative activities. The CCF-project takes an integrated approach to address aspects ranging from interior design and information technology to software support and work organization.

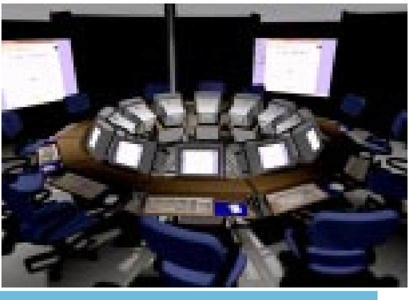


Fig. 1. CCF in the Ars Electronica Center

Real-world financial and technological constraints forced the use of existing components. Many rather ambitious ideas and approaches have not just being discussed, they must be implemented and evaluated under real-world conditions. One important aspect was the user need of using standard software, e.g., Office-Suites on MS-Windows platform.

From a technical point of view the implementation of a CSCW (MS-Windows based) environment under above restrictions results in a very inhomogeneous set of software and hardware respectively with a lot of work to be done for evaluation to ensure compatibly.

2 Room Management Considerations

The interior components building a modern conference room offering computational, communicative and audio/video services form a scenario which is an example for embedding systems in an environment thus building a platform for studying some aspects of Weiser's (1993) idea of "Ubiquitous Computing".

2.1 Existing systems

Commercial available Room Control Systems, such as ADCOM's (1994) iRoom or AMX's (1993) AXCESS system allow configuration of (multimedia) hardware components offering "matrix-based" user interfaces for connecting and scheduling of special devices and workplaces. Each row corresponds to a multimedia source device (eg. Camera, VCR output) and each column to a destination, the visitor view on a monitor

Copperstock et. al (1995) describes their evolutionary room control design based on a traditional matrix-based user-interface, the "virtual graphical patchbay" for controlling a working conference room which is equipped to support a broad class of meetings and media. Additionally integration of sensors with various devices allows the modeling of a virtual "skilled operator" to drive the room. The virtual operator supports the user in managing difficult room-management tasks.

Sandusky (1997) discusses the implications on network management as one form of infrastructure management in CSCW-domains. Lavana *et al.* (1997) have developed an internet-based desktop environment with drag-and-drop assembling of configurable execution sequences on data and applications transparently residing on different hosts realizing a workflow environment.

2.2 Devices

The advanced hardware components of the CCF-environment, e.g. electronic whiteboards, ISDN-conferencing, room observing camera, videoserver etc., are controlled via dedicated software interfaces linked to remote software modules (DLLs) which control the special processes for CCFs hardware units on its host-computers. Thus RMS realized the hardware control via accessing remote software modules for the specialized hardware components like existing Room Control Systems.

2.3 Group unaware applications

The users interact with the environment via programs running on different computers, their application scenarios. The design of the CCF controlling mechanisms must consider the dynamic (ex)change of the program palette offered to the users. The controlling mechanisms could not base on technical standards used only by a subset from the available programs.

Principally application sharing technology is a generic way to control and observe application scenarios on other computers. In the CCF application sharing allows some aspects of cooperative work on not group aware applications.

Application sharing tools are unable to visualize or control not identical application scenarios on more than one computer because they only share many visualizations of one application.

2.4 Group aware applications, "the missing link"

Synchronous working group aware applications, e.g., shared editors and whiteboards build the center of the CCF functionality. The "missing link" for an adequate usability, especially for no-computer-experts, is an instance that is able to start and control the application scenarios from the different participants. Shared workspaces are implemented within most group aware applications; exiting participants leave the shared workspace. E.g., the BSCW (Basic Support for Cooperative Work) system provided by Bently *et al.* (1995) has to be initialized by starting an internet-browser with the appropriate address. Without help from a tool an ordinary tutor with a no-computer-expert profile moderating a lecture in with many participants will waste time to start the lecture.

At an initial phase of a course taking place in the CCF a tutor should be able to start the appropriate parameterized application scenario on each client station. During the course he needs an overview of all the application scenarios of the participants. For a detailed view of one participant is used either the group aware functionality of the application scenario or application sharing technology.

Existing room control systems only deal with managing the complex hardware scenarios of conference rooms. They don't bridge the gap to manage additionally the concurrent running complex application scenarios. The granularity of operations of room control systems is the computer/device level for instance screens (as units for collaborative working on) are shared or redirected. Similar coarse is the granularity of collaborative interactions within application sharing tools. The granularity of collaborative objects within group aware applications is much finer. RMS tries to integrate these objects (devices, shared applications, shared objects) of different levels of granularity, momentary "enclosed" in encapsulated worlds.

Appelt *et al.* (1996) describe access rights, member administration within a group concept as integral part of the BSCW system, this is typical for CSCW applications. Sidler *et al.* (1997) more generally extends the model of the WWW to include its users for enabling many new WWW-based applications. RMS additionally synthesizes member- and computer administration (both organized in groups) and their access rights and operation possibilities (e.g., offered multimedia facilities by a dedicated computer) respectively into one workplace concept. Applications within the application scenarios use this information via software interfaces. Thus RMS integrates user management functionality of typical CSCW systems with task/process management functionality of an operating system and computer/device management functionality of traditional room control systems.

2.5 Synonyms

No-computer-experts use the terms “User” and “Computer” often synonymously. In Cooperative Buildings this set of synonymously used terms will be expand by, e.g., furniture. For the end-users it becomes more and more difficult to decide what the causal chain of observable events is. In the CCF this tendency could be noticed for the electronic whiteboards that are seamless integrated in the wall. The knowledge that an electronic whiteboard is a special screen device of an ordinary computer is necessary to understand some room functionality. A room control system should assist the user in managing those devices, for instance allowing synonyms for computer, furniture and devices.

The RMS models its clients, the CCF-objects, as tuples consisting of user, computer and furniture, e.g., a wheeled table at a position within a scenario. A scenario is a collection of positions. Each element of a CCF-tuple-object can be marked as “unknown” or “anonymous” respectively. E.g., the (read only) video-wall is modeled as CCF-object with the “admin” user, or externally, from outside of the CCF, participating users are modeled as CCF-objects with “unknown” positions. CCF-objects can be selected via a wide range of synonyms, either

- (name of) user or
- (name of) user group or
- (address of) computer or
- (name of) computer group or
- (name of) table or
- (coordinates of) position respectively.

2.6 Identification

For no-computer-experts the identification of CCF-objects like users and computer via email- or internet-addresses is problematic. Therefore the different interior objects of the CCF as the wheeled computer-tables, computers and special devices are colored and additionally labeled with pictograms. Pictures of the users are stored. Visualizing the CCF-objects using icons and pictures improve the usability by no-computer-experts. The authentication of the users and their access to their personalized data is initiated by their personal chipcards.

An active badge location system as proposed by Want *et al.* (1992) for users and (wireless) computers would be the ideal solution for building an user interface synchronously positioning the CCF objects at their appropriate scenario positions. The chipcard-concept forces the semi-manual configuration of the computers within the room scenario. The relation "user-computer" which maintenance is triggered by introducing user chipcards seems sufficient for the relatively small CCF scenario.

A room control system should prevent the user from identifying objects with the appropriate logical key, it should support the addressing of objects via selection out of a graphical visualized set of objects.

3 The Room Management System

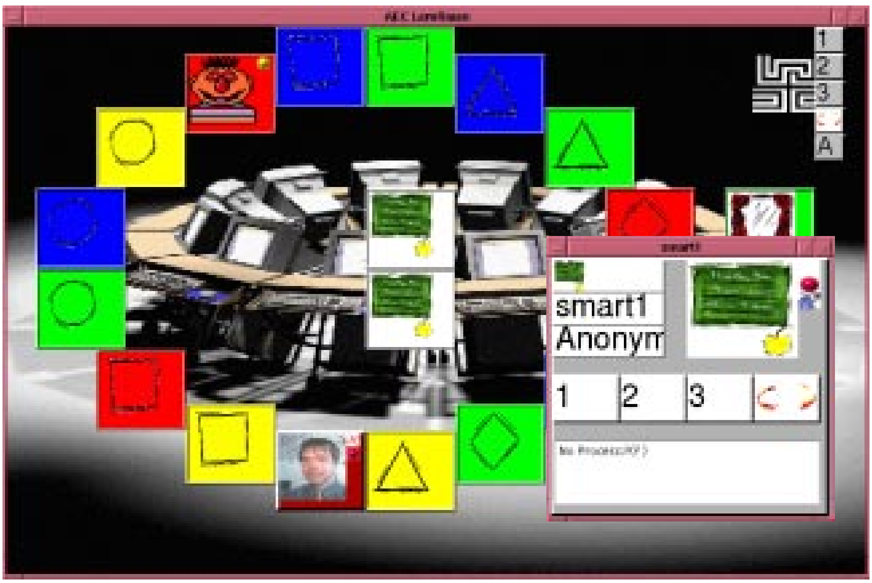


Fig. 2. GUI of the RMS

3.1 Visualization

The RMS visualization arranges the CCF Objects similar to their physical positions. A scenario is a set of positions. Each position can contain a computer or device respectively. The RMS can switch between different scenarios or can manipulate them. Thus RMS takes in account, that the CCF wheeled computer-tables can be moved through the room. Because the moveable devices can't report their physical place the match between reality and RMS visualization have to be done manually.

The RMS visualizes the CCF-objects as tupels of computers and users at scenario locations. The association of computer to a scenario position must be initially configured, the association between user and computer is built with the chipcard information of the computers chipcard-device.

A user-picture could be grabbed at each table by an optionally installed desktop camera. “Unknown” positions of external participants are visualized in a separate window. If the user-picture is unavailable the computer-icon is drawn. If the computer at a special scenario location is unknown the icon of the appropriate table is drawn.

3.2 Multiple selection

The user interface allows multiple selection of CCF objects; commands selected via popup-menus are executed on each member of such a selection. Additionally groups of CCF-objects can be built. On a group or selection of CCF objects actions could be initialized, e.g., start or stop of a dedicated program (on each selection member). The program-command-lines are configurable for each client via ASCII-format. Each command-line is labeled with a unique key and can contain token representing the actual selection of CCF objects. The available actions on a group of CCF objects are those with a common key. Additionally constraints optionally validate and modify the current selection of CCF objects. E.g., a note must contain at least one receiver; the set automatically is expanded with the sending CCF object. A command-line could be a sequence of subcommands; thus complete application scenarios involving a group of users and computers can be centrally initiated. All configured actions can be attributed with the necessary role the current user must have or computer properties that have to be enabled. Only actions satisfying the actual role on selections with appropriate computers are listed within the dynamically generated popup menus.

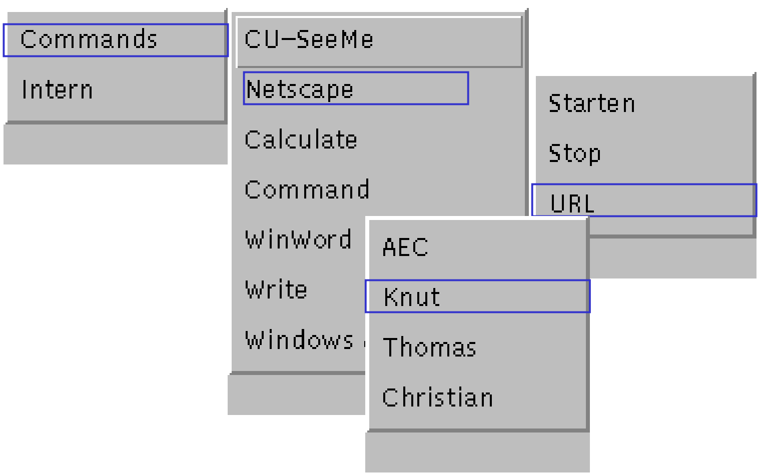


Fig. 3. Popup to start a http-page on each of the selected clients

One of the regularly used actions is the simultaneous display of html- pages on every member of the CCF- object- selection thus realizing and controlling a “guided Internet tour”. Thus RMS (together with its awareness indicators) realizes the functionality of a collaborative browser, e.g., as proposed by Sidler (1997) with the CoBrowse-project.

The process states of a group of CCF objects can be observed. The process-states are kept for the applications and their associated windows. The process-state of a group of CCF Objects is implemented as matching process-states of the group members. A (group-) process-state is visualized as a popup-menu, containing running processes and associated windows. This menu expands each process with a start/stop submenu and each window with a submenu of commands like "to foreground, maximize, iconize, close …". Constraints formulate the maximal number of instances one application can have. Patterns for applications and windows that should be observable can be configured.

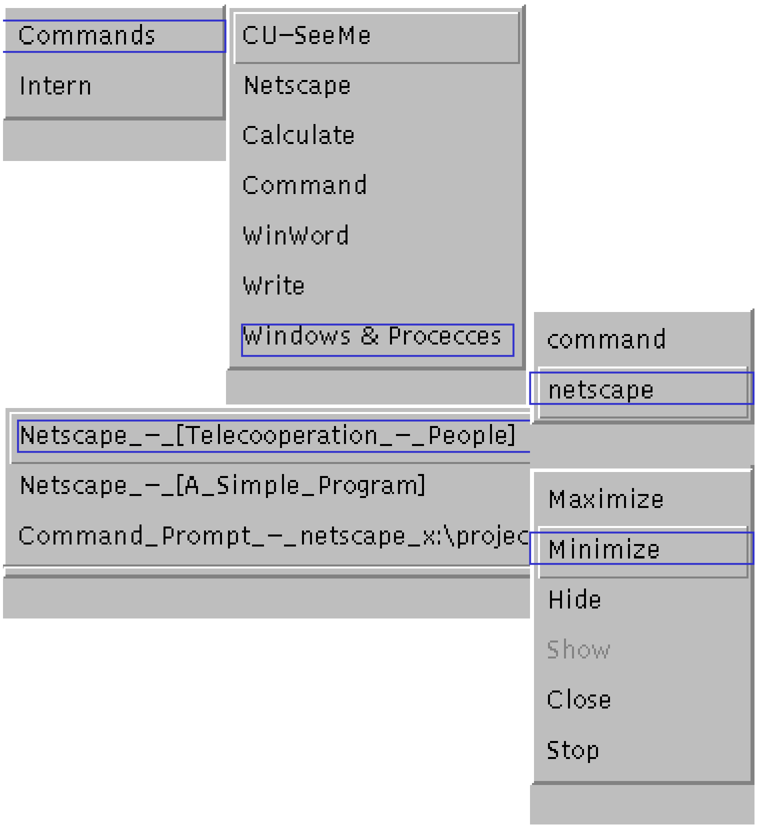


Fig. 4. Modifying common windows on selected clients

3.3 Awareness

The workplaces are labeled with icons visualizing the state of the appropriate RMS client. A RMS object is a tuple of a computer (and its position) with the user logged in. The state of a client-computer as one member of a CCF-object has the range of {“Computer turned off”, “Computer running without RMS Client”, “RMS client running”, “This computer”}. Additionally the RMS updates in regularly intervals of time the user pictures realizing a kind of “Lightweight Conferencing” as described by Sidler (1997). All RMS-model changes are broadcast to the other clients. Duncan *et al.* (1995) discuss information about the connectivity, presence, focus, and activity in an environment that is part virtual and part real. They exploit the use of media to provide assurances; graphics can, in part, convey presence while audio can, in part, convey activity. Similar RMS exploits the information about introduced chipcards, client process states etc. for generating awareness information.

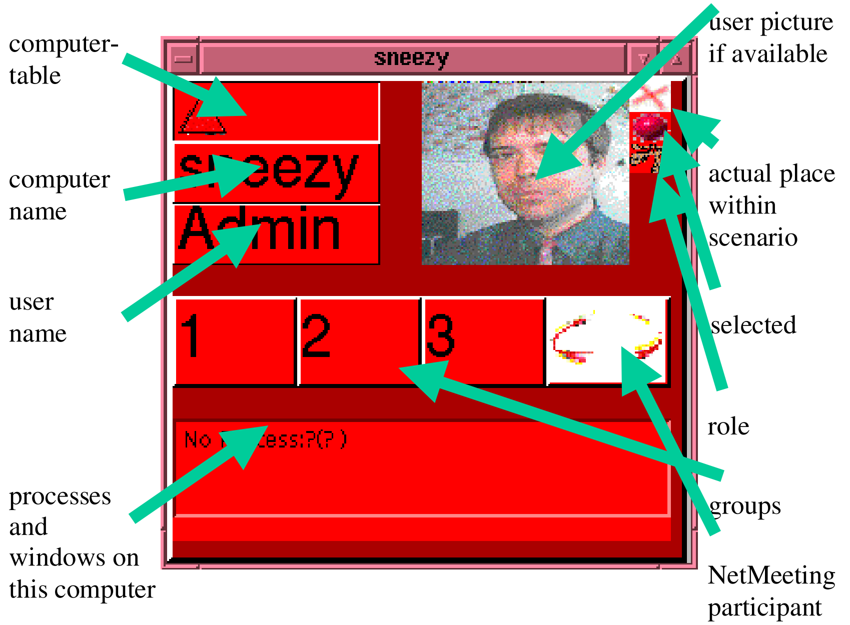


Fig. 5. RMS detailed client

3.4 Application sharing

The application-sharing tool used in the CCF is Microsoft’s (1997) –NetMeeting, also containing other generic CSCW tools as Chat and a collaborative Whiteboard. Like other similar tools the management of the sharing participants is delegated to all clients. During lectures taking place in the CCF we made the experience that using multi-point-application sharing often results in time-wasting coordination tasks for resolving conflicts or even explain the current software- behavior. We noticed that no-computer-experts that have difficulties to understand what application- sharing really does are not able to manage their client for taking part in an application-sharing session. With RMS a tutor is able for setting up a group of application -sharing participants through one central action. RMS synchronizes its information about the CCF-objects (users and their associated computers) with the NetMeeting-repository. The repeatedly needed task for resetting an application sharing session is centrally managed by RMS.

3.5 Device control

RMS remotely makes available the control of dedicated devices. E.g., the movement of the room-observing camera is controllable via a serial port on a dedicated computer. The RMS-client on this computer received a logical position from another client and transforms this to the appropriate control sequence. Also other special devices, e.g., the video-wall have their specific control panels.

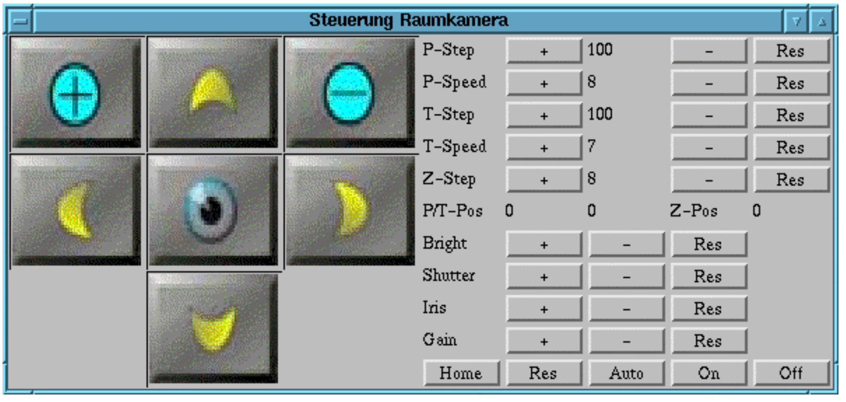


Fig. 6. Control panel for the room-observing camera

3.6 Implementation details

The RMS is a client server system. The server is implemented as N-1-unicast reflector. Model changes are broadcast to the other synchronously working clients. An alternative implementation realizes a multicast server.

Server and client sites are implemented with JAVA. The optional server multicast component and the client components that are controlling the devices or are watching the computer process space are realized as DLLs. The client-specific configuration data, e.g., what processes are available or should be observed, are stored within html-pages.

Clients with no available DLLs are able to observe and control the CCF activities, e.g., from outside of the CCF. Clients with no configured RMS-DLL are not controllable or observable caused by the restrictions through Sun's conception (1996) of the JAVA-security-manager.

User pictures are broadcast in a DCT-compressed form. NetMeeting is controlled via the appropriate NetMeeting-SDK.

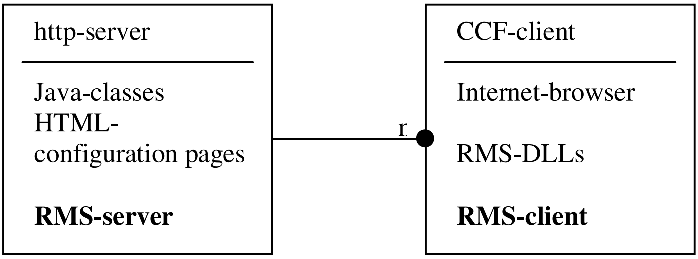


Fig. 7. Client Server

4 CCF Objects of the Room Management System

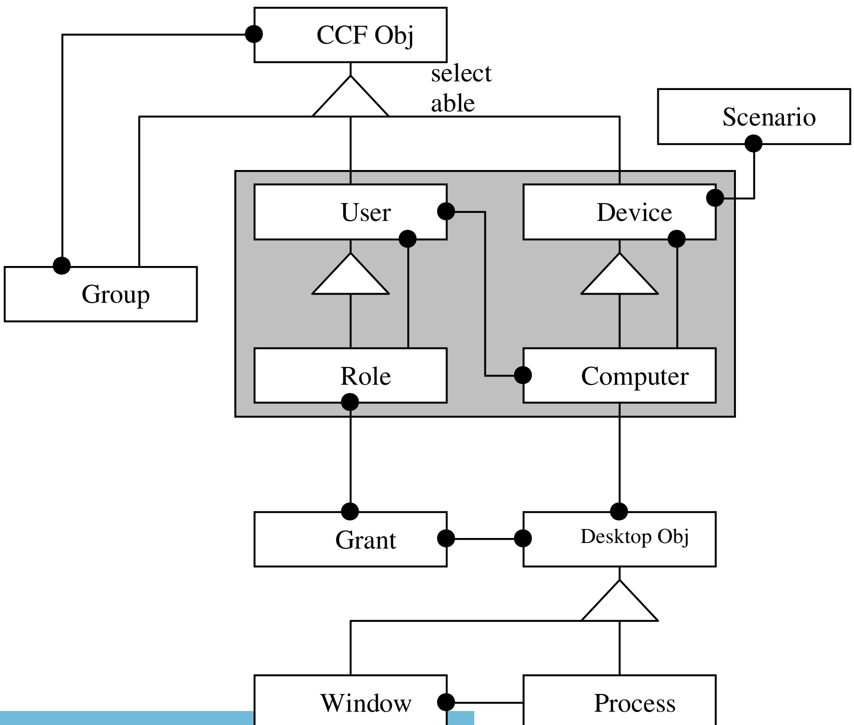


Fig. 8. Basic classes of the Room Management System

5 Conclusion

With RMS, we propose a first step in integration of control for distributed software and distributed hardware via extending room control facilities with generic functionality for managing application scenarios. The project is ongoing and there remains a great deal to do for seamless integration RMS into a courseware environment.

References

1. ADCOM (1994). *iRoom™ Room Control Systems*. Product Information, http://adcom.ca/iroom/iroom.html
2. AMX Corporation (1993). *Advanced Remote Control Systems*. Product Information.
3. Appelt, W., & Busbach, U. (1996). The BSCW System: A WWW based Application to Support Cooperation of Distributed Groups, *WET ICE 96: Collaborating on the Internet: The World-Wide Web and Beyond (Stanford University, June 19-21, 1996*)
4. Bentley, R., Horstmann, T., Sikkel, K., & Trevor, T.: Supporting collaborative information sharing with the World-Wide Web: The BSCW Shared Workspace system". In: *4th International WWW Conference, Boston, MS (December 1995*)
5. Copperstock, J., Tanikoshi, K., Beirne, G., Narine, T., & Buxton, W. (1995). Evolution of a Reactive Environment. In: *Proceedings of the CHI 1995* (Denver, Colerado, USA, May 7-11, 1995).
6. Lavana, H., Khetawat, A., & Brglez, F. (1997). A Paradigm for Dynamically Reconfigurable Desktop Environments, In: *Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work (GROUP 97)* (Phoenix, Arizona, USA, November 16-19, 1997), ACM-Press, 204-213.
7. Microsoft Corporation (1997). *Netmeeting*, Product Information. http://www.eu.microsoft.com/netmeeting.
8. Mühlhäuser, M., Borchers, J. , Falkowski, C., & Manske, K. (1996). The Conference/Classroom of the Future: An interdisciplinary approach. In: *Proc. of the IFIP Conference The International Office of the Future: Design Options and Solution Strategies* (University of Arizona, Tucson, USA, April 9-11, 1996), Chapman and Hall, 233-250.
9. Sandusky, R.: Infrastructure Mangement as Cooperative Work: Implications for Systems Design, In: *Proc. of the International ACM SIGGROUP Conference on Supporting Group Work (GROUP 97)* (Phoenix, USA, November 16-19, 1997), ACM-Press, 1997, 91-100.
10. Seligmann, D., Mercury, T., & Edmark, J. (1995). Providing assurances in a multimedia interactive environment. In: Proceedings of the CHI 1995 Conference *Human Factors in Computing Systems* (Denver, Colorado, USA, May 7-11, 1995).
11. Sidler, G., Scott, A., & Wolf, H. (1997). Collaborative Browsing in the World Wide Web. In: *Proc. of the 8th Joint European Networking Conference* (Edinburgh, May 12-15, 1997)
12. Sun Inc.: "Java Security". http://www.javasoft.com/security/whitepaper.ps
13. Want, R., Hopper, A., Falcao, V., Gibbons, J. (1992). The Active Badge Location System. *ACM Transactions on Information Systems*, 1992, 10(1): 91-102.
14. Weiser, M. (1993). Some Computer Science Issues in Ubiquitous Computing. *Communications of the ACM*, 36 (7), 75-83.

The Dwelling as a Place for Work

Stefan Junestrand[1] & Konrad Tollmar[2]

The Royal Institute of Technology
[1]Department of Architectural Design and Technology
[2]CID - Centre for User-Oriented IT Design
100 44 Stockholm, Sweden
Email: s.junestrand@arch.kth.se, konrad@nada.kth.se

Abstract. This paper will discuss the future use of the dwelling as a place for cooperative work. It is our opinion that the development of the communication technologies and the architectural design has to be treated in parallel when we discuss new forms of living and work habits. Our analysis is built on a theoretical framework that is reflected through earlier experiences in IT technology in domestic environments as well as field studies of computer-mediated communication. By taking into consideration both architectural and communication technology issues we have developed a framework of how these two areas could fruitfully meet in new design concepts. Some of these concepts are now being used in on-going projects where new forms of communication in domestic environments are studied.

Keywords. architecture, computer supported cooperative work (CSCW), video-communication, telework, dwelling, ambient media

1 Introduction

The purpose of this paper is to describe some aspects on how a future dwelling architecture could be developed and how the communication technologies could be integrated to support cooperative work activities in a domestic environment. The analysis is built on a theoretical backbone reflected through experiences in CSCW (Tollmar *et al.,* 1996, 1997), as well as field studies of IT in domestic environments (Hunhammar *et al.,* 1996). A wider context will be presented by analysing the historical development as well as some trends and scenarios for the future.

The dwelling is meant primarily to support the activity "to live". So, when the way of living is changing the design of the dwelling also changes. Compare, for example, the radical difference between a dwelling of the agricultural society of the 17th century and an industrial worker's home in 1960's. We are now experiencing a major change in our way of living in the transition from an industrial society to an information society. Our hypothesis is, therefore, that the dwelling of the information society has to be designed in a radically new way, than the dwelling of the industrial society.

Our key argument is that we will spend more and more time in our homes, where we will also accomplish a wider range of activities, including professional work. The reasons for increased work, and cooperative work as well, in our homes are - despite the prerequisites of available IT tools - among others (Forsebäck, 1995; Graham and Marvin, 1996):

- New social trends and values in a diversified individual perspective where the limits between the private, e.g. the family life, and the public, e.g. work, are loosening up.
- Changing organisational and economical structure within companies and organisations.
- New attitudes from a political view, both national and international.

The widened range of activities in the domestic life and the technology push will lead to an extended need for communication facilities. These will diversify into a set of communication units for different kinds of use. The motivation for acquiring some technologies in domestic environments might even be derived from the dual purpose of fulfilling both social and professional needs.

One way of understanding different kinds of communication systems is to utilize architectural metaphors in our interpretation of a system. To date, it seems that the imitation of architectural or urban spaces has been the dominant strategy for most of the multi-media telepresence systems (Mitchell, 1995). All of these electronic systems are based on a rationale of projecting architectural props into an electronic space, i.e. a room or a table. We would like to argue that such metaphors should be pushed even further.

The major goal with this paper is to work out a framework where we can play around with concepts in modern architecture and communication technologies. This paper focuses on architectural and IT-communicative perspectives of dwellings in Sweden and primarily for a growing group of people working in the information sector. Of the different components that computer supported cooperative work consists of we will focus on the live video and audio communication. The paper, in current scope, will it not include any deeper discussion about e.g. social, economical or political aspects. However, all are additional important facts of the implications of the new IT technologies for the society of the future.

2 Scenarios of the Dwelling, Future Life and Work Style

Two scenarios are developed showing different situations where live video communication forms a part of work and spare time activities. It is our hope that the scenarios might work as an introduction to the complex situation of new needs and possibilities involved in the field of new communication technologies and the architectural design of the dwelling.

The scenarios take place in a eleven stories residential building in a Stockholm suburb. People living in the house well represent the new dominating group working in the service and information sector. The year is 2010…

“When the kids comes home”

It’s 4.15 p.m. a Thursday in May and David, a married father of two twin daughters is at home working, just as most days of the week. Now he sits in a semi-transparent glass-cube, which is a sort of transit from the staircase to the apartment. He’s having a business videoconference.
- Okay David, your comments on the design were great, says Roberto on the big screen. I will do the changes and call you back when it’s done. Anyway how are you wife and kids?
- Great, thank you Roberto! Wait, I can see Maria and Sara coming here in the staircase. They are in the hallway now; maybe you can see them coming. They have been to school this afternoon.
- Hi Maria and Sara, welcome home, says David to his daughters. - Say hello to Roberto, a friend of dad who lives in Brasilia. Maria take a step forward and waves her hand to the video screen. And says: - Hello Roberto, I’m Maria. - Hi Maria, answers Roberto, I like your backpack! - Oh really, says Maria, It’s my portable computer, I need it for school.
- Alright Roberto, see you soon and send my regards to your family, finishes David.
The screen automatically shuts down and David pushes the movable wall and places it in front of the glass panel leading to the staircase. By doing so he converts the hall into a more private space than the public working space he needed during the day. At the same time he takes the chair he was sitting in and moves it close to the panorama window. Then he turns the chair upside down and suddenly it becomes a comfortable rocking chair for reading a book later at night…

“Talking to grand-ma“

It is evening, 6.30 p.m. The father and the youngest son are watching the children TV together. A “virtual agent” asks if they are willing to take an incoming call from the grand-ma. Steve, the father, replies:
- Yes, of course, you don’t have to ask for that, put her through … Hi mom, how are you doing?
- I’m fine, how are you John? I’m sorry to interrupt you in the middle of your TV show.
- That’s ok, what’s on your mind?
- Well its John’s birthday next week so I thought that I should ask if he has any special wish.
John replies immediately: - Yes I would like some new pieces to my Lego robot.
- Grand-Ma ; That sounds expensive! But we will see. Could I talk just to you Steve, and Maria (the mother) so John can continue to watch his show?
- Yes of course, says Steve, I think Maria is still in the car, so let us meet in the kitchen in a minute.
- Okay, I wait for you there, replies Grand-Ma.
Steve re-routes the call to the kitchen with the help from his “virtual agent“, and ask it to locate Maria…

3 Architectural Concepts

The most important concepts in the development of the architecture of the dwelling are primarily: time and space and the concept to live. The concept of time and space are important depending on where, when and how one actually does things - in this case to 'live in your home'. The concept live in an architectural perspective is a condition for the being and the space that can not be separated (Norberg-Schultz, 1971).

3.1 The dwelling

Historically the activities in the agricultural society where often integrated both in time and in space. Work and idle time where not separate concepts and the whole household participated in the daily work. The majority of activities took place inside or around the buildings. The dwelling was the physical form of the way to survive, and the form was decided by practical and ecological conditions.

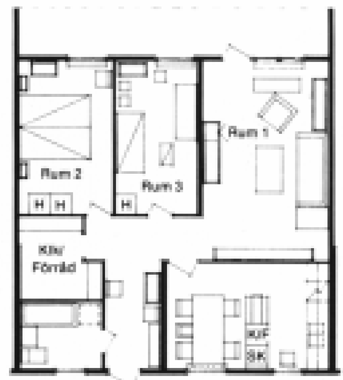


Fig.1. Plan of a Swedish farm with spaces for the majority of the household's activities spread out in different buildings united in one physical form.

Fig. 2. Plan of a typical apartment of the 70s, showing an obvious division of some of our different functional activities into spaces.

The industrial revolution lead to the division of 'work' and 'live' for the majority of the population and the dwelling turned into a "machine to live in". The dwelling was now designed for: homework, personal needs, spare time activities and studies for the young generation. The professional work was no longer a part of the dwelling and should be done in the fabrics or at the offices. The activities where separated in time and space with the dwelling at one place, the workplace at a second and the central functions at a third, all tied together through private or public transportation.

The dwelling of the information society will again, probably, represent a wider spectrum of activities integrated in time and space. What will happen is that we, to a much greater extent than today, will work from home, shop from home and take care of the elder population in their homes with support from different IT solutions.

3.2 The concept of time

"Einstein's theory of relativity introduces into physics a notion of time that is intrinsically flexible. Although it did not quite restore

> the ancient mystical ideas of time as essentially personal and subjective, it did tie the experience of time firmly to the individual observer. No longer could one talk of the time - only my time and your time, depending on how we are moving. To use the catch phrase: time is relative."
> *(Davies 1995)*

Time might apparently be a very simple concept, but it is actually extremely complex and has many ways of interpretation. Here we will, in the first place, focus on how we relate to time. We will also discuss how time is perceived. Worthwhile to notice is that the way we in general relate to time is well behind the more scientific or intellectual understanding of the concept.

In the old agricultural society the relationship to time can be described as circular. The reason for this comes from two directions. One comes from the very nature itself and one origin from the philosophical ideas of Plato. With "from the nature itself" is understood the cyclical character of the nature - the repeating character of the day, the week and the year (Davies, 1995). Practically, this relation to time resulted in an adaptation to the nature's outer factors. Philosophically, the circular understanding of time was the way Plato described the time from a more scientific point of view. This model has left deep marks in the western culture.

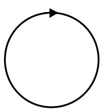
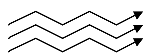
RELATIONS TO TIME			
	"CIRCULAR"	"LINEAR"	"PLURALISTIC-SUBJECTIVE"
GRAFICAL ILLUSTRATION OF THE RELATION TO TIME			
SCIENTIFIC REPRESAT	PLATO	NEWTON	BOLTZMAN
HISTORICAL EROACH	"AGRICULTURAL SOCIETY"	"INDUSTRIAL SOCIETY"	"INFORMATION SOCIETY"

Fig. 3. Graphical illustration of different relations to time in different historical epochs with an indication to identify who originally represented this point of view - in a scientific way

The industrial society's demand of an exact and chronological order in production and distribution changed the concept of time from circular to linear (Davies, 1995). There had been an acceptance of an order of time in earlier cultures. But that time could be something precise and objective became possible with the modern science (Davies, 1995). Most things such as production of goods and services where measured in time and time studies where done even of activities in the dwelling, e.g., house-wives work in the kitchen.

Time in the information society will rather be perceived as *pluralistic* and *subjective*. Time will be treated as related to: rhythm, length, speed and quality (Mead &

Pacione, 1996; Philips, 1996). More concrete this could mean that we might feel that the "time is running by" or that something "goes on for ever". In a more global world of information, this new conception of time, means that it's more important what we produce and not when and where we do it. This results in more flexible and individual forms of work and everyday life.

We will be connected and prepared to communicate any second of the day. This will obviously cause problem in domestic environments, in particularly how to handle quality in time - both focus as individuals and as family members. Should, e.g., *all* phones-calls be re-directed towards the answering machine during the family dinner?

3.3 The concept of space

> "Architecture is the thoughtful making of spaces. The continual renewal of architecture comes from changing concepts of space."
> *Louis I. Kahn*

The concept of space refers to what Norberg-Schultz (1971) describe as: "architectural space may be understood as a concretization of environmental schemata or images, which form a necessary part of man's general orientation or 'being in the world' ". Man has not always only existed and acted in space, but also created spaces as an expression of their understanding of the world. The architectural space and man's way to relate to and act in it have changed over time.

In the industrial society the concept of space became scientifically rational and in general a spatial result of the analysed function which would take place within it. The dwellings got sleeping rooms, bathrooms and living rooms. The need, will and belief in structuring and classifying even the spaces became important. The American architect Louis Sullivan founded the expression "form follows function", during the late 19th century.

The concept of space in the information society is becoming more complex and can be understood as two parallel spaces: *the electronic* and *the physical*. The electronic space consists of one *representative* space such as virtual reality and another *abstract* space which refers to an non-hierarchical one with free associations and parallel places (Mead & Pacione, 1996). The physical space, on the other hand, is the single world where we actually are with our bodies. Hence, the electronic space is global while the physical space becomes more and more local when we spend more of our lives in and around our dwellings.

3.4 Private and public

In the agricultural society where the limits between what we today define as private and public spaces not yet defined. People lived and worked inside the farms main building, outside close to the buildings, or on the fields as a group, i.e., many people slept in the same rooms and beds and the "toilets" consisted of many holes in a row (Rybczynski, 1988).

The concept of public and private has during the industrial age developed and become something really important. The private became absolutely private and public became totally public. The earlier public characters in, e.g., traditional farmers house disappeared in the modern planning. The limits between public and private became sharp; compare for example the public character of a staircase and the very privacy of the apartments hall in a typical residential building of the later decades. Norberg-Schultz (1971) describe this phenomenon as “We have already mentioned variation in the public and the private aspects of the dwelling, and hinted at the fact that modern man to a large extent has lost the level of nature”.

The way to live in our homes in the information society is becoming more complex and with an increasing integration between work, shopping and domestic activities, the limits of private and public will open up (Graham and Marvin, 1996). We will also experience new ways of communicating. The technology will, e.g., permit us to break limitations in physical proximity by real-time video communications. Radically different means of connecting places is that everyone can “be their own television broadcaster” and make, i.e., a family home page that opens up the physical family household environment to become more public.

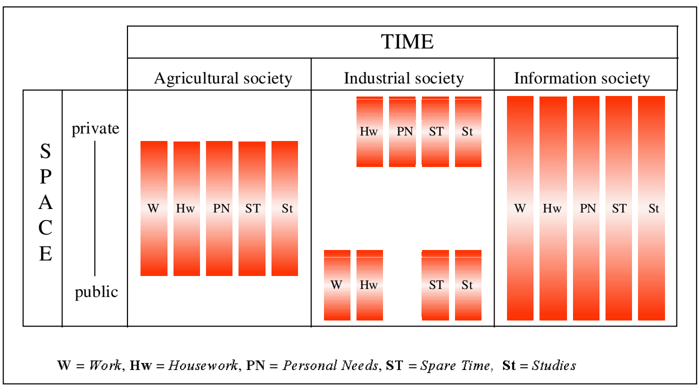


Fig. 4. A schematic image over how activities in our everyday-life are located in a private-public aspect over the epochs.

4 Basic Communication

> “Many of the significant issues in differentiation arise from the physical environments from which we enter "virtual" spaces; the existencies of particular, local situations lead to variations in virtual behaviour. The homogeneity of distributed communities is often illusory.“
> *(Dourish, 1997)*

As the time spent in domestic environment will increase and the activities will undergo changes, the need for new communication facilities will grow. These will diversify into a set of communication units for different kinds of use. We will now discuss some of the implications new communication technique might incur for the domestic environment.

Given the variety of communication in domestic environments one must emphases on the needed flexibility. Another key factor is to stress the importance of social interaction among members facilitated by work or by common ties. We may take this a step further and note that in designing domestic communication facilities, the following core attributes might be crucial in creating a sense of accessibility and proximity:

- Finding people and information.
- Creating and sharing social space and workspace.
- Keeping track of events and participating in the governance.
- Use and control of communication media.

Our starting point is the number of prototypes, usability studies and fieldstudies, that have been undertaken on mainly video-communication facilities, e.g. mediaspaces (a virtual space mediated a communication act over distance), within the CSCW (Computer supported cooperative work) community. Previous research on video-communication has revealed many contradictions in our understanding of this communication media. Issues like non-verbal communication and media quality has been heavily debated in the literature (Whittaker, 1995). In the context of this work have privacy concerns turned out to be of special interest. In particular, as some places of the future dwelling will become semi-public places, like the family hallway, a dilemma exists where the private, individual, and public space meets. Paul Dourish has reported (1997) about the continuous efforts to experiment with different solutions to privacy issues in mediaspaces. Durish pointed out the contradiction of the nature of mediaspaces as hybrid physical / virtual environments.

4.1 Architectural interpretation of communication media

One way of understanding different kinds of communication systems is to use physical metaphors in our interpretation of the system. To this day, it seems as if the imitation of architectural and urban spaces has been the dominant strategy for most computer meditated communication systems.

In, e.g., the University of Toronto's video-conference system (Mantei *et al*., 1991) a part of the interface consists of small thumb-tack windows, with names underneath of people, who are potentially available for a video-conference. If a person is in her office, a small picture her is displayed, if they would rather not be disturbed, a "half-closed door" reveals only part of the face, and if they really do not want to be interrupted, there is a "DO NOT DISTURB" sign. The design principle was to transpose everyday interaction rituals to an electronic world, based on the social meaning of physical artefacts (i.e. half-closed doors). Architectural props, were used as symbols of an individual's desire for engaging in certain kinds of social (electronically mediated) interaction ("I am busy but if it's really important you can interrupt me with a video-conference").

The intended purpose of such features is to allow the transposition of everyday conversational mechanisms into mediated communication. The essence of this point is an emphasis of the emergence of designing the physical space so it has the affordance of being both virtually and physically shared. The work by William Mitchell (1995) gives us some further references. Mitchell makes a parallel between successful new electronic places and how the urban space was designed in the ancient Greek *agora*, “It was the possession of an agora that made a collection of buildings a city“. Mitchell lists four major characteristics that make a space *agora* like:

- Accessibility, open.
- Friendliness, non-hostile.
- Freedom of assembly and action, providing high level of freedom in action.
- Public control of use and transformation over time.

Another worthy source is Ray Oldenburg’s (1989) analysis of the concept “third places” in his book “The Great Good Place: Cafes, Coffee Shops, Community Centres, Beauty Parlours, General Stores, Bars, Hangouts, and How They Get You Through the Day”. Third places are, according to Oldenburg, neither home nor work, but are places where informal public life can take place. Third places around the world share common and essential features, they are levellers - inclusive rather than exclusive and expand social possibilities.

However it’s our standpoint that most imitations of architectural and urban space and places that are used in today’s development of communication systems are too crude and superficial. We all know that clever architectural design is like a clever interface - intuitive, attractive and transparent in a subtle combination. In a physical space it is all these subtleties that shape or do not shape the communication within a building, office, public bar etc. Designer of today’s electronic communication media unfortunately do not push and advocate the architectural metaphors far enough.

4.2 Create and share social and work space

In our latest research project in video-communication, the VideoCafe project (Tollmar *et al.*, 1997), we started from an idea of virtually connected public places in two research labs that were about to initiate an collaborative research program. The idea of providing a public mediaspace was built on the assumption that such a space could act as a facilitator for informal community building. By empowering the individuals to be able to take an active part in the discussion and change future plans and activities.

One of the core activities in the VideoCafe project was to experiment with a couple of different room designs. For that purpose we created both new social places in workplaces as well as new styles of interior design that could foster a community.[1]

- In connection to shared communication devices (see Fig. 5),
- For lobbies (see Fig. 6),

[1] All the places that we here discuss are located within or close to what now is CID (Center for User oriented IT Design) at the Royal Institute of Technology, Stockholm, Sweden. The different interior design solutions for the other research lab at Ericsson MediaLab are discussed elsewhere (Tollmar *et al.*, 1997).

- For shared laboratories (see Fig. 7),
- For public lunchrooms (see Fig. 8,9).

4.2.1 The Corridor

Fig. 5. The VideoCafe concept placed in a corridor.

A corridor was the first place of installation (see Fig. 5). The place was close other communication infrastructure, such as faxes, Xerox machines and mailboxes. It also was close to some of the staff member's offices. In general, it could be described as the place through which everybody had a reason to pass, several times per day.Our basic idea was to enrich this place of encounters with the remote lab's presence, but since it literally affected everyone in the lab in a very direct way, several privacy considerations were undertaken to give the place the affordance of different communication zones. The place was divided into three different zones:

- an inner zone where the user could be both seen and heard,
- the background zone where the user could be seen but not heard,
- a free zone where you are neither heard nor seen to be used, for example, by people passing through whom would like to be left alone.

In practice it turned out to be hard to strictly, but flexibly, control the technology in such way that the different zones were clearly distinguished. If you were engaged in a conversation it was hard to protect that conversation, and the place could actually also exhibit a hostile character due to the problem of shielding a conversation. In addition, we found a problem in the fact that public places tend to be owned by their neighbours. What the corridor place lacked in agora terminology was, despite it is accessibility, obviously some proportion of friendliness.

4.2.2 The Lobby

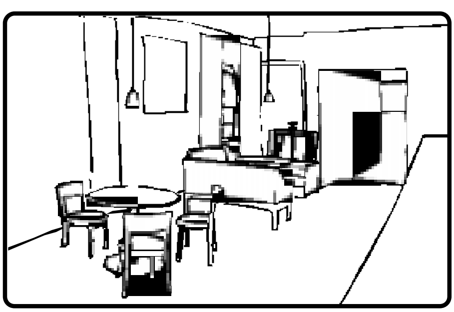


Fig. 6. The VideoCafe concept placed in a lobby.

The second place for our prototype was a lobby. The lobby has a more defined role, and is mostly no-mans land. Furthermore, compared to the corridor, it is usually not that heavily trafficked and hence provides a calmer atmosphere for longer conversations (see Fig. 6).

However, in our case this place did not work at all. Comments that were made indicated that this is a place of merely pass through, and very seldom a place where you stop to chat. The frequency of informal encounters dropped noticeably. However, compared to the corridor, this place supported better semi-formal meetings between the labs. Due to its calm nature it became a greater place for extended meetings.

4.2.3 The Lab

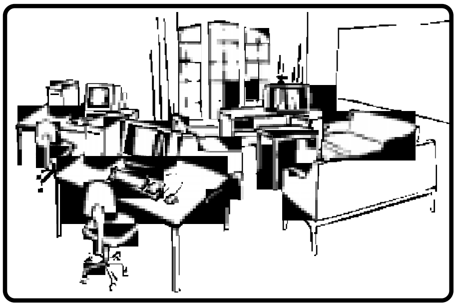


Fig. 7. The VideoCafe concept placed in the lab.

Our next step was to find a place, which combined the positive aspects from the lobby with the possibilities to, afforded the frequent encounters that the corridor did. The place selected was the common lab. To handle the more tricky privacy issues in the lab, eye-dropping and audio pollution, we removed one of the zones in this prototype. Hence we limited the available zones to two, the inner zone where you can be both seen and heard, and the free zone where you neither are heard nor seen (see Fig. 7).

It became apparent that people working in the lab sometimes, naturally, turned the volume down not to be disturbed in their work. Since the audio maybe is the most essential medium for peripheral awareness the need to reduce the volume came into direct conflict with the casual interactions idea, e.g. when people notice the rattle of keys when a person at the other site lock her door at the end of the day. The basic lesson of the lab place experiment was that we needed to add extra interaction devices to our design. Dependent on where you were standing in the room, the communication devices need to adjust to that specific situation. E.g. if people only move around in the free-zone the audio level should be adjusted as well as the camera being positioned into a small, closed field of view.

Another way of solving this is to replace the direct audio with some ambient form of a less intrusive nature. However this form of media-transformation is a complex matter where we have only started to define our needs and have so far only a rudimentary set of conceptual design experiments.

4.2.4 The Kitchen

Taking into consideration the reflections above, particularly that too many of the lab members felt that efficiency was negatively effected by the VideoCafe's presence in the lab, we experienced rather soon a consensus of the necessity of try out a new place. The new place we selected was a half-open self-service kitchen in connection to the main entrance to CID (see Fig. 8 and 9).

One of the key problems which we observed during the earlier prototypes was the difference between people sitting down, plausibly engaged in some conversation and people passing through. To be able to work with this, and related issues, we decided to design and build our own tables and chairs according to our needs. The solution was a raised table in the form of a bar. Our basic idea was two-folded, firstly, we lowered the threshold in the initiation of the conversation and secondly we provided a place for short, spontaneous interactions (see Fig. 8).

A problem in the earlier prototypes was that the space did not clearly suggest how many people it was designed for. One of the outcomes of this was that the distance between the participants always varied towards the camera, the microphones and the screen. The shape of the new table also ensured that most participants had a fixed distance between each other. In addition to the tables' two level boards it become possible to separate the hang-around functions with techniques necessary in this settings, remote control, miles of cables, microphones etc.

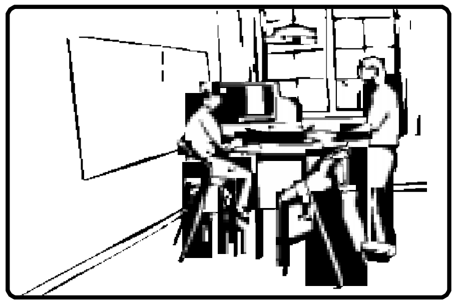


Fig. 8. The VideoCafe with a specially designed furniture with the two different tables levels for communication devices and the service-area for the user's coffee, papers and pens

Fig. 9. The VideoCafe concept placed as a café with a piece of specially designed furniture.

4.3 Use and control of communication media

In our findings three kinds of control veers feedback, system, audio and visual have been identified as critical. Most important is that the user must be able to control the volume of the received audio and turn on and off the audio transmission. An active user must also be able to control his / hers visual field at the opposite site, as well as be given a visual feedback of the video-picture that are sent to the opposite site. We have formulated our experience in two categories of guidelines - how to form the audio-room and how to control the field of vision.

Many earlier studies have shown that the audio quality is an important factor (Tang & Isaacs, 1993). In our studies we have been trying to obtain one shared audio-room by using directed audio with CD-quality. Points of interest are in this case to find models for audio visualisation of the shared room to enable equivalent conditions for conversations as in face-to-face conversations in physical room, e.g., back-channels for several simultaneous discussions. This turned out to be a very complicated matter to solve. The basic problem is that every single room audio-acoustic properties differ tremendously from all other rooms, it's like a room's unique fingerprint. No-matter how the audio is processed there will exist a difference in the character of the speech in the physical rooms compared to the transmitted speech from the remote location. Our work-around solution is to filter the audio with extra-ordinary circumspection. But, like in many other design solutions for the VideoCafe, this will raise a subtle balancing act. The trade-off is to make the speech as good as possible at the expense of reducing the background audio, that is so important for awareness mechanisms.

When people sit in the same room they are able to control their own field of vision by moving their head and body 360 degrees and the participants can immediately see in which direction another person is looking. To be able to achieve some freedom in the field of vision for the remote participants we have experimented with using several video cameras at each site. These cameras can then smoothly provide both overview pictures of the room as well as close-ups. To simplify the interaction with these video cameras a simple IR-control device was developed that controlled both local as well as remote cameras. Nevertheless, in practice we found that contradictory to these features most users instead utilises the space to control distance between participants. For example by placing themselves in the room instead of using the zoom function to zoom in a person they are talking with. This stress even further the question of providing even simpler forms, e.g. a remote control, of interaction devices to control the field of vision. One example in this direction is to use different kinds of motion and presence detectors that could perform camera, as well as audio, adjustments.

4.4 Conclusions from basic communication

IT technology is already referred to as a natural component in the way many of us live. Increasing and changing ways of communication will in itself demand new architectural distribution and design of the dwelling. Implementing this for both professional work and social aspects in the context of the dwelling will require more from the technology. With transparent interfaces, intermixed with special devices, it will be possible to focus upon communication instead of technology. Experiences from the use of mediaspaces, that so far primarily have been developed for office buildings, will raise new design-criteria's that seem to be interesting for the dwelling:

- The technology must afford a large degree of flexibility connected to the use of space in the dwelling. It must be possible to transfer a call to another place if the discussion shifts and gets too intrusive for the environment. The space should also afford people to connect to a discussion.
- If a permanent link is connected to places apart there exists big needs of additional levels of communication, sometimes the mediaspace is too noisy and intrusive and in other occasions it is too passive and does not afford that kind of casual communication it is intended for.
- The need for a comfortable and easy interface not distracting the communication act but allowing on-the-fly adjustments of the technology could never be over-exaggerated.
- Problems concerning interior design issues are colour and lightning. Firstly the interior colours need to be colours that can be transmitted with video without

distortion. Secondly, does lightning have to be a compromise between the studio lightning and the lightning of a living room.

- Of great importance is also how to create a shared context in the interior that provides an "us" feeling between two rooms.

5 Discussion

The dwelling in the 21st century might not at all mean the same thing as in the 1990's. In the 21st century people will have a greater part of their everyday activities in and around the dwelling. This includes both traditional home-related activities and professional work. The border between homework and professional work will loosen up. Fewer people will have a permanent employment and more will work in temporary projects or run their own business, with the home as their stable and fixed point. A greater number of these activities, i.e. professional work, shopping on Internet, care of elder people and childen, and video-telephony, will also be supported by different kinds of communication technologies. The dwelling will in this context function as the physical base of one's existence.

5.1 New use of communication media

From our studies of video-communication we have found two interesting strands of further development that might be of special interest for the appliance of mediaspaces technologies in domestic environments. Firstly, there exist a big need of different levels of communication. Sometimes the mediaspace is to noisy and intrusive and on other occasions the mediaspace is too passive and cannot allow the kind of casual communication that it is intended for. Different forms of media transformations seem here to be a promising direction for further development. Secondly, even a simple function like adjusting the camera with a remote control could easily create breakdowns in the discussion. An alternative kind of interface that utilise the position and the gestures of the body in the room could be a comfortable and easy alternative interface.

It's our standpoint that concers regarding privacy, a major source to problems in office environments, will only be more important to handle properly if we want to move this kind of communication techniques into domestic environments. Our new direction is to examine some alternative solutions where some media undertake some transformation into new forms, media forms that maybe is not direct and intrusive. It might be wanted to, in some domestic environments, make it possible to hear, rather than see, where other things or people are and what they do. Both due to privacy concerns but also to practical concerns since it is not possible to look around every corner in a domestic environment. Like cord-less phones, we would like to enable users to freely move around and let other more practical factors decide where the communication act takes place.

A mix of the above questions yields a generic issue; *could the room adjust itself to different levels of communication?* Depending on people's position and activity, e.g. use of other services. We are especially interested in investigating different kinds of mechanisms that, in a semiautomatic way, based on preferences and physical controls, help the user to adjust to a suitable level of communication. Today, we are working with motion and image detectors to adjust audio and visual fields in our system. A general guideline is to build the interface as transparently as possible, the ideal is that you will be able to use your body in the room as the main interaction device.

5.2 The architectural and communicative expression

Although the later part of this paper focuses on communicative aspects in the use and design of the dwelling, we will here continue the architectural discussion from the first part of the paper. Lately some architects who have intended to approach IT and communication aspects in the dwelling have done this from a view that the use and meaning of the dwelling is something permanent, and not something that develops with a changing of the way of life. Therefore we discuss some general aspects of a future architecture.

Architecture has always expressed some of the fundamental ideas of the time in which it was created. The information age will be unhierarhical, subjective and flexible among other characteristics and so will it is architecture. Rather than 'tearing down and building new' as in the industrial age, reconstruction, addition and extension will be the dominating way in the construction of the information society. The huge number of existing dwellings will experience a great change to adapt to new and changing needs in the information society. New building elements and techniques will probably be mixed with traditional ways of building. The architectural expression will therefore be a mixture of old and new ideals, forms and materials. Sensors will be built into materials, building components, machines and furniture are meant to collect and transmit information. This will add to traditional ideas about architectural elements and expressions, a new dimension and meaning.

Some architectural design ideas and concepts have been developed from the above discussion. These are here presented in a wider sense:

- There will be an extended number of activities taking place in the homes and these will vary during the day and the week. The average time spent at home will also increase, which means that with maintenance of today's use of space will be a needed to adapt the dwelling according to the activities taking place at the moment. A solution might be *flexible and moveable walls and wall-systems* that could provide spaces adequate for the changing activities.
- Apartments from the industrial ages are generally very closed towards any public space and of a strict private character. There are reasons to expect an increasing need to physically *open up* the apartments towards the public staircase, e.g. with glassed walls or new physical forms.
- Changing and more extended use of the buildings *common spaces* for activities such as meetings, delivery of products and tele-work in favour of e.g. laundry and storage will take place. These semi-public places will in this way temporarily be-

come more private. The borders between the public and private will in this sense be more flexible and diffuse.

- The lack of space and the different characters of the varying activities will also demand a wider use of the furniture in domestic environments. Today a bed, table or chair normally is designed only for one single function. But there will be an increasing demand for multifunctional furniture, adaptable - in colour, size, form and other characteristics - to different activities and situations.

Another overall aspect is that these technologies, building components and furniture not only have to be able to adapt to different situations but also to personal needs and habits.

5.3 Future work

An architectural design solution for distribution of video-communication that we are working on is to divide spaces in the dwelling into *different zones* were each zone has an intuitive clear communication mode, as we above argued. The zones may vary over the time and so might the spaces' forms and functions. From this, a more specific architectural and communicative design concept might be developed mutually. A design which is a combination of technology solutions and physically building components.

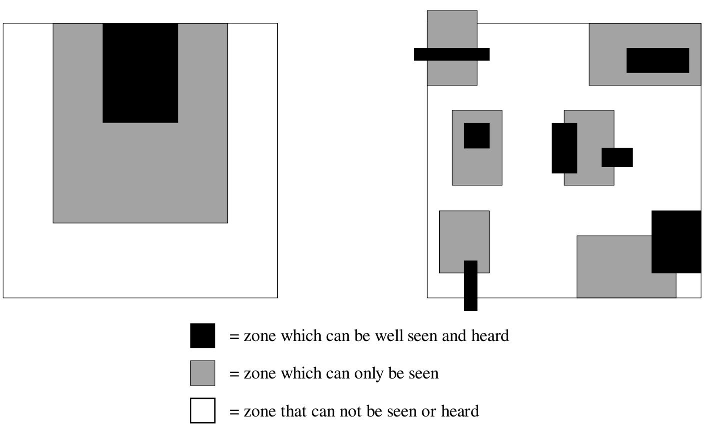


Fig. 10. Graphical illustrations of conceptual communication designs.

To the left: Traditional hierarchical design concept for dwellings with one zone placed at a strategic point such as the hallway.

To the right: Alternative "network-floorplan" - developed by the authors - with flexible zones distributed over the apartment.

From our experience it is also clear that this kind of places would strongly benefit from more subtle communication qualities. Qualities, which may not be found in improved video or audio sampling frequency, but qualities that might significantly enrich the experience of remote places through communication technology. We have, thus, in on-going projects started to explore new spatial and artifactual tools to address other experiences as a complement to the functional media provided by audio and video. The origin of these tools comes from a context of everyday life. The goal is to replace the ambient communication that is obviously lost between remote places but might be replaced by artificial spaces. To illustrate this further we finnish this paper here with some brief examples; imagine a connection between a pair of chairs, if one of them is used the other one will also be heated to indicate (tele)presence, a lamp could be connected to a remote piezo sensors or stretch sensors that toggled on/off depending on remote presence, or that connected places share temperature, air humidity and lightness. Our working hypothesis is that restrictions, for example for privacy concerns - which are of particularly interest for domestic environments, in direct media, could be replaced by incorporating this kind of ambient media.

Acknowledgements

Extraordinary valuable contributions to this work have been made by; Britt Klasson, Tomas Stephanson and Didier Chicholle who were our Ericsson partner in VideoCafe project. Robert Mittel gratefully designed and built as his master's project in the interior design program, our new set of furniture. Olle Torgny nicely did the art work. Staffan Liljegren at Ericsson Telecom Medialab funded the ATM-based video-codec and other hardware, and Stockholm Gigabit Network (SGN) generously provided us with as much fibre as we wanted. Finally we would like to thank our professors Ulf Keijer and Yngve Sundblad for their unvaluable support during this work.

References

1. Ambrose, I. & Nielsen, J. S. R. (1997). *Informations- och kommunikationsteknologi i fremtidens boliger*, (Information and communication technologies in the dwellings of the future) , SBI-Rapport 284, Hörsholm, Denmark.
2. Caso, O. & Tacken, M. (1993). *TELEMATICS IN RESIDENTIAL AREAS - Spatial Effects for Dwelling and Neighbourhood*, Publikatieburo Bouwkunde, Delft University, Netherlands.
3. Chermayeff, S. & Alexander, C. (1963). *Community and Privacy: Towards a New Architecture of Humanism.* Garden City, NY: Anchor Books.
4. Davies, P. (1995). *About time*, London: Viking.
5. Dourish, P. (1997). Different Strokes for Different Folks:Privacy Norms in Three Media Spaces, In: *SIG-GROUP Bullentin* 1:2, ACM, June/July1997.
6. Forsebäck, L. (1995). 20 seconds to work, Home-based telework, Swedish experiences in an European perspective, State of the art 1995, Teldok report 101E, Stockholm.
7. Gideon, S. (1963). Space, time and architecture: the growth of a new tradition. Cambridge Mass.: MIT Press.
8. Graham, & Marvin (1996). Telecommunication and the City: Electronic Spaces, *Urban Places,* Routledge, London.
9. Hall, E. (1969). *The Hidden Dimension*. Garden City, NY: Doubleday & Co. Inc.

10. Hunhammar, M., Junestrand, S., Keijer, U. & Spets, K. (1996). Measuring and Evaluation of IT-supported Service Infrastructures in the Built Environment - SIBElab, Paper presented at the *European Network for Housing Conference - New Communication Technologies for Housing*, Helsingör, Denmark, August 26th - 30th 1996.
11. Lynch, K. (1960). *The Image of the City*. Cambridge MA: MIT Press.
12. Mantei, M., Baecker, R., Sellen, A., Buxton, W., Milligan, T. and Wellman, B. (1991). Experiences in the Use of a Media Space, In: *Proceedings of the ACM Conference on Human Factors in Computing Systems CHI'91*, New Orleans, Lo.
13. Mead, P., & Pacione, C. (1996). Time and Space, *Interactions* Vol. 1, 68-76.
14. Mehrabian, A. (1976). Public places and private Spaces: The Psychology of Work, Play, and Living Environments, Basic Books Inc.
15. Mitchell, W. (1995). *City of Bits - Space, Place, and the infobahn*, Cambridge MA: MIT Press.
16. Norberg-Schulz (1971). *Existence, Space & Architecture*, London: Studio Vista.
17. Oldenburg, R. (1989). The Great Good Place: Cafes, Coffee Shops, Community Centres, .. Hangouts, and How They Get You Through the Day, New York: Paragon House.
18. Philips Corporate Design (1996). *Vision of the Future*, V+K Publishing, Bussum, The Netherlands, (also http://www.philips.com/design/vof).
19. Ridley, B. K. (1995). *Time, space and things*, Cambridge: Cambridge University Press.
20. Rybczynski, W. (1987). *Home: A Short History of an Idea*, Penguin.
21. Simon, H.A. (1981). *The Science of the Artificial*, Cambridge, Mass.: MIT Press.
22. Tang, J. and Isaacs, E. (1993). "Why Do Users Like Video? Studies of Multimedia-Supported Collaboration", *Computer Supported Cooperative Work*, 1(3), 163-196.
23. Tollmar K., Sandor O. & Schömer A. (1996). Supporting Social Awareness @Work - Design and Experience, In: *Proceedings of CSCW´96*, Boston: ACM Press.
24. Tollmar K, Klasson B. & Stephanson T. (1997). VideoCafe - Virtual Espresso-Cafés And Semi-Located Communities, CID tech report TRITA-NA-D9719. (also submitted to CHI´98)
25. Whittaker, S. (1995), Rethinking video as a technology for interpersonal communications: theory and design implications, *Int. Journal of Man-Machine Studies*, 42.

Understanding Technology in Domestic Environments: Lessons for Cooperative Buildings

John Hughes, Jon O'Brien and Tom Rodden

Sociology and Computing Departments
Lancaster University
Lancaster, LA1 4YR, UK.
Tel: +44 1524 594186
Email: [j.hughes,j.obrien2,t.rodden]@lancaster.ac.uk

Abstract. This paper considers the nature of interactive technology within domestic environments and how we might want to consider the design of technology for domestic environments. As part of this work it highlights the methodological issues faced in the design of systems for the home environments. The shortage of detailed knowledge of activities in the home is highlighted as a major issue in understanding the situated nature of technologies. A series of studies of domestic environments is presented alongside the design challenges they raise.

Keywords. domestic environments, interactive technology, home environments, cooperative buildings, methodological issues

1 Introduction

The last decade has seen a shift in the common perception of computer systems and how they are used. Both the IT industry and Government bodies in the USA and Europe have started to focus on the impact of moving computers into the home (Venkatesh, 1996). Many people envisage the development and deployment of novel interaction devices within these environments and the general amendment of domestic environments to support novel forms of interaction. It is clear that the provision of network facilities to the home will have significant impact and that the systems deployed will support cooperative interaction. However, what is less clear is what form these systems will take and the impact they will have on domestic environments.

It is easy to conjecture that technological devices will play a significant role in the formation of domestic environments and the shaping of the home of the future. Occupants of domestic environments will use technological artefacts to mould their environment and provide support for their day to day activities. However, what is currently less clear in what ways people may seek to exploit these technologies as a means of designing the cooperative domestic environments in which they are placed. We currently lack a clear understanding of the relationship between these technological artefacts the nature of the spaces they find themselves in and the activities that take place within the home.

In this paper we wish to turn to a series of studies of households to consider the nature of homes as places that are distinct from other environments and the implications they have for the future development of cooperative buildings. Prior to doing so we wish to reflect on the methodological challenges to the design of systems and environments posed by the emergence of the home as a setting for computer applications that are closely bound to the environment in which they are placed. The core of our message is that the nature of domestic environments is intimately bound up with the technology placed within it and is often formed with and through this technology. In designing artefacts to be placed within these environments we are essentially designing the cooperative environment itself and must develop an understanding of the nature of this environment. To this end we present an on-going study of the nature of households and the role of technology in everyday activities and, consequently, briefly reflect on the potential implications of this study for the design of future domestic environments. The paper concludes considering some of the more general preliminary lessons from these studies.

2 The Move to the Household

It is now widely realised that the home is likely to prove an important site for new information technologies; technologies which do not necessarily have to be migrated from the industrial or work sphere to the domestic.[1] This view requires a shift in the manner in which designers perceive the future use of computer systems. Until now computer systems have focused on consideration of the dedicated support of particular work activities in isolation of the environment in which these systems are placed. Consequently, design techniques have focused on supporting the construction of dedicated applications to support particular forms of work rather than a broader consideration of the application and the space within which it may be used.

The almost wholesale shift toward an 'information society' that a consideration of cooperative buildings embraces suggests that future designers will increase their repertoire of tools to understand the context within which systems are place. However, in terms of domestic environments one of the major inhibiting factors to the eventual realisation of this shift is the paucity of detailed information we currently have about the household and the role of technology within the home.

The relatively recent 1993 Report of the EC's European Foundation for the Improvement of Living and Working Conditions (Moran, 1993) criticises the lack of effort that had been expended on studying home life and the implications of such technologies for daily life. After discussing initiatives in the US, Japan and Europe, the report comments:

> "A major criticism can be levelled at all three initiatives. No model of the home or its users has been developed which could underlie developments in the Electronic Home area. The initiatives are largely the result of a "technology push" type approach. A clear conceptual paradigm has not emerged ... The decision by all three major actors ... to carry out research on the experiences of real householders is to be welcomed.

---

[1]Venkatesh(1996) identifies the telecommunications, information, computer and entertainment industries as now treating the home as the next site for technological development:

> This will provide valuable feedback on user needs and requirements on which the viability of the initiatives from a market perspective ultimately depends."

In general, existing approaches to understanding domestic environments and activities within the home have been undertaken with the purpose of developing a broader view of the nature of society. Consequently, studies of domestic environments have focused on developing information that can be readily aggregated to speak of sections of society or geographic regions. In can be argued that rather than treating daily activities in the home as a topic of enquiry in their own right, most studies treat such details as a resource to be mobilised in support of some form of broader social theory. Those ’qualitative’ studies of the home that do exist (e.g., (Hirsch, 1992), (Hobson, 1982), (Lull, 1982) (Morley, 1980; Morley, 1986) and (Silverstone, 1994)) tend to situate such assessment of the household within sociological debates concerning such topics as modernity and alienation, the suburbanisation of the public sphere, nationhood and globalisation. Here the qualitative data is, post hoc, ’slotted into’ sociological debate, and offered as ’evidence’ for or against such broader issues rather than treated as a topic in its own right.

Many approaches to understanding technology in the home characterise it in terms of the ’patterns of ownership’ of IT and related leisure technology owned in the home (see for example (Mackay, 1995)). This approach attempts to draw inferences from sets of statistics that are then aggregated to provide assertions about the role these pieces of technology play within the home.

These existing methodological approaches rely upon a certain degree of ’schematisation’ of social phenomena to which the complexity of daily life does not necessarily lend itself. Existing studies essentially construct a theoretical gloss of the actual nature of the relationship between information technology and the home. What is unclear is the extent to which this form of investigation can provide the detailed insights into the activities of the home suitable for the designers of future domestic environments populated by IT systems.

The development of cooperative buildings for the home will require designers to outline both hardware and software suitable for use in the home. Rather than simply migrate existing approaches to design, which focus on work environments, designers will need to examine the utility of existing approaches. The development of methods, tools and techniques suitable for these environments represents in itself a research challenge for future designers. It is essential that these techniques and tools be based on an understanding of home environments. This in turn requires to undertake initial studies of the home to inform the development of these methods and techniques.

As part of our contribution to the growth of a corpus of knowledge of the home we have undertaken a series of ethnographic studies intended to sensitise designers and developers to the character of ‘real world’ household domains. More specifically, the study’s objective was to bring out some of the social dimensions of households - in much the same way in which this has been achieved for work settings in CSCW - relevant to the potential uses of new domestic technologies. It is important, we are arguing, to design these technologies with a more grounded understanding of existing patterns of social interactions to serve as a baseline in order to better assess not only how one might think about such technologies but also, and as important, obtain a better sense of those aspects of household sub-cultures which design would need to take into account.

3 Understanding the Home

We undertook a six-month period of ethnographically informed studies of a range of UK homes, during which time a single fieldworker spent three evening visits with families from a number of households. The findings from these studies were used to feed into the design and development work of a major UK telecom access products manufacturer in the area of Residential Broadband Networks and their associated domestic technologies. The design remit was the provision of future information services within domestic environments. Essentially, the provision of the core IT facilities need to realise a cooperative building. The participating households were selected in order that a reasonable range of households were covered, with emphasis on covering different economic, geographic and family backgrounds in the sample of households..

Ethnographic studies of work and organisation have become reasonably commonplace within the field of Computer Supported Cooperative Work (CSCW), and are very much concerned with providing a detailed of a given application domain as a resource for the design and development of systems that are to operate within that domain. The rationale of ethnography as undertaken by many within the realm of CSCW is such that the object of its endeavour is to display the social organisation of activities by those who are party to the situation under observation from the perspective of these social actors. It is this ambition which necessitates a 'fieldworker' (typically a trained social scientist) becoming involved in the setting and the activities being studied in order to gain the same perspective, as far as this is possible, of the actors concerned.

In the context of this project it was considered vital to gain an understanding of the natural sociality of domestic environments, studying interaction within its natural 'real world' settings, in a way which would minimise disruption to the household. Accordingly it was decided that the most appropriate form of ethnographic study would be one based around a series of evening visits to participating households, rather than the more prolonged periods of study of even the briefest ethnographic enquiries within work organisations. Such prolonged periods if study were deemed to be too problematic within the period of study

4 Emergent Themes in Domestic Environments

We were interested in generating an understanding of the nature of the home as a 'lived in' environment, and the ways in which technology was, quite literally, 'made at home' in such an environment. It is our contention that there are a number of important ways in which an understanding of the relationship between the 'lived space' of the home and the technology that finds it character within it might provide important lessons for the design and development of 'cooperative buildings' of all types. Accordingly this paper outlines some important elements of this relationship and draws a number of conclusions from these themes.

4.1 Aesthetic elements of the home

The aesthetic character of participants' dwellings was a non-trivial element of the transformation of 'a house' into 'a home', and as such was greatly valued by participants as an important characteristic of their dwelling. It became clear that participants' houses were 'worked at' and made into 'homes' by the decoration and configuration of the home. This is something which all participants undertook in some form or another, although often not particularly concertedly as one participant claimed (although many might argue that being able 'to build a room' constitutes more than mere handyman status) :

M "I don't spend a lot of time doing it, but I do think I'm quite a handyman ... so I built a room in the last house we were in, and I fitted the kitchen there, and when we came here, actually I got somebody else to do the kitchen, but I did do most of the work up there [C's bedroom] ... we still haven't got round to decorating here but I think that it's such a huge room that all you can do is get your white paint brush out again, there's just no prospect of doing anything else in here"

Fitted units in their bedroom.

Doesn't feel he does a lot, but feels he can do anything required, including plumbing, ... he's added bits to the central heating system.

Enjoys it because

M "You feel as if you've genuinely achieved something at the end of it ... 'Here's this loo I installed I can sit on it all day! What a clever boy am I!" [All laugh].

This work was characterised by its distinct and highly personal nature as we see in the following description of the front room of one participant's house:

F "I sit in there quite a lot now ... yeah I use it quite a lot and I had really set ideas about what I wanted. I wanted stripy wall paper and I wanted bookshelves in the recesses in the walls. I wanted a desk just like I've got and, you know, everything's been ... I knew what I wanted."

This concerted construction of a place 'to feel at home in' was in evidence even when participants houses were rented or had not been lived in for a long period. Here a young couple living in rented accommodation outline their attempts to make themselves feel 'at home':

F "... to be honest if I had the money I would ... yeah I would do it out differently, you know I'd rent an empty house, put my own furniture in it, because I wouldn't choose a lot of stuff in the house"

M "I would like to do that as well ... you know, it still feels like a rented house ... it's not our stuff actually ..."

F " ... yeah I've got used to it, 'cause I've lived here for a few years, so kind of take it for granted a bit, but yeah ... sometimes I get really frustrated, 'cause I want to do things like not have those horrible brown curtains [Laughs] even though they're good quality and they're warm and everything, they're not very attractive."

M "The brown can be a bit over bearing sometimes!"

F [Laughs] that's something we've tried to do to 'make it ours', we've tried to put some colour in the house!"

Furniture belongs to landlord - he suggested that they do some decorating -

F "it was quite nice to do it, because it makes you feel like ... 'cause we chose the colour, although he sort of said 'I don't want anything outrageous', so we had to kind of agree it with him. Got our own pictures up, most of our own, kind of plants and ... "

M "... ornaments ..."

F " ... pots and ..."

M " ... moved ... we've moved all the stuff 'round as we like it ... "

F " … changed… "

M " … yeah we've changed the layout"

F " … yeah we've taken stuff out and put it in the garage and said 'we don't want this' … there was two sets of shelves and we couldn't fit them in so we've taken one out …"

M "Taken loads of books, um …"

F " … yeah we've got the landlord to get rid of stuff"

Although participants clearly had a range of financial resources to call upon in undertaking such ’home making’ activities it was clear that all participants undertook such activities in whatever way they could with the result that the aesthetic nature of the house was of utmost importance to them. Here we are not just referring to people ’keeping the house clean” but to the kinds of decoration, ornamentation and configuration that the house is subjected to in order to ’be home’, choices which obviously reflect the character and lifestyle of householders within it. It is also worth noting as an important caveat that there is a close relationship between the aesthetic and practical organisation of home.

4.2 Privacy

Despite this ’public’ face of the home, privacy is also a closely guarded feature of all homes, and is indeed seen as one of the major constitutive elements making the home distinct from other locations.

M "One of the things that I don't like about living here, is the fact that, we've realised that everybody can hear exactly what you're doing"

F "Yeah they're not very soundproofed … if you have a row, say … 'cause I've been outside and I've heard people rowing … and we were talking about this with our neighbours the other night, 'cause they'd heard a huge row going on next door at New Year and we've had rows, and we're thinking 'Oh God! People will have heard everything that we've said'!" [Laughs]

M "Yeah that's right, 'cause like you can hear people talking outside when they're getting out of their cars and stuff … so I don't like … well I'd like somewhere that was a bit more private … busy yet secluded! [Laughs]

F "It's sort of private in a lot of ways because you've got a garden to sit in and you don't have lots of people walking past, staring at you … you're neighbours over the back can see you if they're upstairs, but … so it's private in that sense, but then in other ways it's quite nosy"

Observations such as these raise an interesting paradox about the household as a private place. It is quite clear, for example, that the household is an exemplar of what we understand private places to be. This privacy is not only enshrined in law but also strongly adhered to in conventions and behaviours of all kinds. In significant respects it is ’good manners’ that one respects the privacy of others. Yet, the above suggestions about the nature of domestic display imply that privacy cannot be understood as simply ’being oneself’ but, on the contrary, involves a great deal of effort in constructing appearances ’for others’, emphasising the importance of both ’privacy’ and ’display’ with regard to the home.

4.3 Ownership of space

Technology in the form of Television, radio and hi-fi were often used to mark out the 'ownership' of space within the home at certain times - householders establish a sophisticated framework of use which speaks to important elements of the social organisation of the home. Certain spaces within the home clearly 'belong' to particular members of the household at particular times as they use particular pieces of technology as this extract from another visit makes clear;

> When their son & daughter lived with them, they had TV's in their rooms. Occasionally would watch together, but would come to arrangements if, when daughter was in there was football - she would go upstairs and watch something else on
>
> M "It was those American soaps, I didn't want to watch them ... err those Australian things ... she'd go upstairs then! Not being funny but the front room and that telly [points to the min television] was definitely mine in those cases ... just like I wouldn't go into her room and tell her what to watch ... that's her space, like "

Such claims to the 'ownership of certain spaces are also closely related to the daily routines of household members. The daily routines of the households are driven by the concerns of work and/or children - these fundamental concerns underwrite the day-to-day existence of householders who organise themselves in order that such mundane yet essential activities get done. Routines emerge because parents must work and children must go to school day in and day out, year on year. Common sense means that sets of actions must emerge which meet these fundamental aims in the least problematic manner - these routines do not 'fall from the sky', as it were, but emerge through the daily activities of householders ordering their lives.

In our study individuals often stated that so-and-so always had to watch this at a certain time to wind down from a stressful day, or had to listen to that in the morning in order to be able to face the world' - and individuals had a precise knowledge of each other's routines and tended to behave in a manner so as not to contravene one another's 'spaces' at such times. In the following extract a couple semi-seriously discuss their respective daily routines and the former makes (exaggeratedly) clear that he orients his behaviour towards not contravening any of the latter's routines;

> M "I do have some routines in the day, but they're still pretty fluid, I mean there's nothing ... I just tend to go with the flow, when I wake up ... whenever that might be! [Laughs] ... but you [to M] are a bit more, you've got a bit more of a routine than me .... to put it bluntly [Laughs] which I would never dare get in the way of!"
>
> F " ... I am the queen of routine! ... I set my alarm for a certain time, 'cause I have to work ... I've got to say if I didn't work the way that I do ... like I set the alarm, and I do try to get up, 'though I often oversleep [Laughs] ... but I do try to and if I get in a pattern then I will stay in it ... I tend to eat lunch at the same time, because I watch Neighbours at the same time ... you could say the television, kind of, is a real ordering factor, I eat when Neighbours is on and I eat dinner when Brookside is on ... it's partly a time thing, though ... everything is caught up with work ... none of this is separable from work, because I'm gonna watch Brookside that means I'm gonna take time off work, so I might as well eat while I'm watching Brookside, whereas if I was a happy person with a normal job then I wouldn't do that."

Such an example might be more over-stated than those found in other households, but it was clear that across the sample of participants people took steps to co-ordinate their activities in such a manner as to avoid problematising one another's routine activities and associated media uses. Of course there are numerous occasions when contraventions of other's routines are deliberately made but these are usually undertaken with the specific intention of causing problems - a goal which is almost invariably achieved in such cases! Such a strategy is successful precisely because individuals are very attached to their own routine uses, and tend to be able to recount them quite specifically, as in this example from members of one family;

> F listens to Radio 4 in the car to get the weather forecast and the news ...
>
> "I tend to turn it off when the news has finished because I don't like the next item on radio 4 ... I put a cassette in , tend to listen to a cassette on the way home, mostly, but sometimes I listen to Radio Cumbria ... newsy, current affairs"
>
> She never puts the radio on around the house ... used to, but now likes the 'peace and quiet', describes this as "excellent"
>
> M always listens to the radio in the car, morning and evening - generally R4 or R Cumbria,
>
> F "I usually switch over when it's the five minute religious slot, unless it's Lionel Blue ... who's always excellent ... then I switch over and listen to Radio Cumbria and occasionally Radio Three and on Sunday morning, I almost invariably get out of bed when everybody else is still sleeping, and I'll read the paper and listen to Radio Three. And sometimes I travel on business and if I'm going a long way I'll put on Classic FM ... but it's bad to get here ... I think I'd probably listen to more Classic FM ...'
>
> F "... I think I'd listen to more Classic FM, but it's so bad to get here ... although the adverts in it drive me potty ..."
>
> M "... I was going to say I really enjoyed it start with and I thought it was a fresh new look at classical music, but it does start to pall a little bit on occasions ..."
>
> F "If you're going a long way in the car .."
>
> M "... and you hear the same damn' advert for the fifth time ... and you think 'Oh for Goodness' Sake'

When they listen and what they listen to is very much engrained in their routine:

5 The Place of Technology within the Home

The configuration of the household and the technology within it reflects the daily routines of those who inhabit and is also manipulated to facilitate and maintain them, so it was common to see 'alternative' televisions, stereos and even (in the case of the one family) videos are provided to ensure that the routines of a number of individuals can be interleaved as harmoniously as possible - for this not to be possible would make homelife an intensely problematic state of affairs.

Of course in referring to the notion of 'routines' we do not wish to imply that householders live out a script day in and day out undertaking the very same activities at precisely the same moment each day. Naturally this cannot be so given the contingencies of everyday life - children are ill and have to stay at home, parents have to work late, visitors drop by unexpectedly and the like - and of course householders react to and these contingencies as a practical matter in order that life can continue around them. Thus, exceptions to the household routine occasion new household configurations and represent the 'public face' of this configuration - for example one family explained that they changed the sofa around to face away from the television and towards the coffee table and other armchairs when visitors came by, a configuration they considered to be 'much more sociable';

> Lay out of main living space fairly constant, apart from the central settee. the central sofa is turned around, facing the TV usually, but they turn it around when they have visitors - see this as a more sociable arrangement.
>
> "You can tell that you constitute a real visitor, 'cause we've turned it round this way"

Furthermore technologies are perceived as having a legitimacy (or lack of it) within this configuration as one family member stated;

F "I object to the television being in the main bit where you're entertaining and things ... if you've got an alternative ... I don't care what it looks like, if I've got friends round for a social evening I don't really want the telly part of it ... I'm not a great telly watcher ... I wouldn't leave the television on when visitors came ..."

S "... but if you were entertaining your visitors then you jolly well shouldn't be having the telly on"

So for example, the television is rarely, if ever left on when guests arrive (it was always switched off whenever the fieldworker visited a house, although videos were often running in order to catch 'must see' programmes), but the use of the HiFi is often acceptable in these situations, and in a number of households the radio was left on throughout the fieldworker's visit.

The important thing to note when considering domestic technologies is that by and large they become 'part of the furniture' and very much absorbed into the fundamental material fabric of each and every home, often in very different ways, but always so that they become contextualised as ordinary, everyday elements of the home, to be replaced or upgraded only when broken. They are perceived very much as there to be at hand doing a basic job, and as long as they do that there is no need to think about replacing them as another couple made clear;

M "We came to the point where the television blows up and you can you look at another television and at that point you say to yourself ... "

F "... What's the best deal I can get?"

M "... what's it worth buying that's available on the market ... so we don't go and buy the cheapest at the time ... but neither do we keep trading up when something new comes up ... and that's the same for anything we do ... it's not we can't afford it, if we wanted to afford it we would, we could ... so we make a value judgement at the time ..."

This can also be said for the video, and to a certain extent HiFi;

TV and video bought not rented ... TV bought quite recently, the previous one they'd had for 15 years ... didn't have a TV for four years and then were given one, and they had that until "blew up" about five years.

They will wait till this one blows up until they replace this one (same with video)

M "Something would have to happen to technology ... you know, for instance, we've upgraded our computer twice ... it's not beyond the bounds of possibility that we might say there's something marvellous and no I don't want that [TV/video] anymore I want to get ... so it's not out the question, that we might upgrade it before it falls apart ... but it would need to be new technology"

F "I mean wouldn't just be because we fancied a new model ..."

M "... Mind you we upgraded my HiFi system ... because, mind you it was very ..."

F " ... It was antediluvian dear! [Laughs]"

M "... It was seriously 'low fi'!"

F "Things had moved on a very long way! It wasn't just wanting a slightly newer model ... it was wanting a different animal"

It is important to note here that such technological artefacts are seen very much as 'doing a fundamental' job and that only the arrival of 'a new technology' would convince them to upgrade. The definition of 'new technology' tended to be associated with marked improvements in functionality, functionality that was deemed to offer positive benefits to the household. Householders put forward 'scenarios of use' when considering new technology. This appears to be the means by which they evaluate the potential contribution such technology might make to their life. In the following extract one participant considers what it might be like to have a videophone in the house to talk with members of her family that live abroad;

> Videophones don't appeal to S:
>
> S "I mean, the phone isn't something we particularly enjoy and want to develop, it's errm ... more of an intrusion, I think it would be awful! If somebody comes out of the bathroom and walks past and the phones out there ... or if you've still got your curlers in! [Laughs]"

Participants often used such scenarios in supporting or attacking arguments for the purchase of new technology, with cases such as 'we'll never have time to use it', 'the kids will be on it all the time' and 'it'll cost too much to run' frequently put forward.

It is in these scenarios that participants appeared to be weighing up the likely benefits of the technology under consideration against its draw backs within their everyday lives, making clear the extent to which such technologies are 'made at home' in the day-to-day worlds of consumers and the notion of too much disruption of the household tended to be a very strong dissuading factor in such decisions.

It is to be noted then, as a corollary of such notions, that the success of the television and its ubiquity in the nations households can be in no small measure due to its ability to support a wide range of viewing regimes, imposing little or no obligations on the household to mould to its requirements, but rather lending itself to and becoming resolutely intertwined with the routine scenarios of everyday existence, whatever they may be.

Indeed the presence of technology within the home is absorbed so completely into the routine practice of homelife that it becomes yet another way in which those routines can be articulated. This much is evidenced by the fact that the control of access to all media, but especially television is seen as an integral element of responsible parenting, as one of the ways in which participants express appropriate control over their children, and attempt to shape them into the 'right' types of people.

Once again it is worth noting that the precise nature of 'the right type of person' aspired to by parents in bringing up their offspring is highly idiosyncratic with such idiosyncrasies reflected in the individualistic nature of the types of access control undertaken by parents. Once again, though the television has become 'made at home' in each household and is successfully subjected to these idiosyncratic regimes, meshing itself into the background of family life, to hand when required and out of the way at other times.

6 The Co-ordination of Homelife

In considering our studies of homelife, domestic routine and the place of technology within that routine and the actual fabric of the house, it became clear that living and action is distributed throughout the home and the extent to which the functionality of certain domestic technologies, so intimately connected with the routine activities through which householders co-ordinate their activities. It is clearly important that householders have the means to continue the routine activities to which they are extremely attached, and functionality is required of domestic technologies in order that this might continue to be achieved. In addition it is worth noting that, to this end, the majority of households also had mobile or at least portable televisions and stereos in order that their functionality could be distributed at will throughout the household.

It is clear that householders tend, as a matter of practical routine, to orient their activities to those of others within the home - they are not simply free to do as they please, and as a result the use of space and technology within the home is a finely tuned equilibrium which, as we have seen, can be 'upset', both deliberately and inadvertently. When this equilibrium breaks down, homelife becomes highly problematic as the following extract from a visit to a single woman, as she explains why she decided to live alone rather than continuing to have lodgers in the house.

> When first lodgers A and T lived there it was fine on the whole, 'though moments of "stress", but when they left - one got married & bought a flat, one finished study and got a job elsewhere in the country - new lodger was more of a problem:
>
> F "We had various hassles over things and I guess it might have just been that I'd got to the point where I didn't really want people sharing my house anymore and I didn't want a studenty-lifestyle or whatever ... but it didn't work out so well and it kind of put me off a bit. I got to the stage where, you know, you'd come in from work and you couldn't relax, 'cause you'd you sort of unlock the door and think 'Is there somebody in the house already?', or you know, 'will there be somebody else coming back in half an hour?' Whereas now I just feel as soon as I'm in the house I just completely relax ... and I really like being able to do that, ... which means that I don't have ... I always used to feel that I had to be here to sort of stamp myself on the place ... have my music on, my radio station in the morning ... I don't know ... I felt like it wasn't mine unless I was here, whereas now it doesn't matter how little I'm here, I still feel at home when I am here. It's horrible isn't it? ... [laughs] ... I hate myself! [laughs]"

The configuration of the household and the technology within it tends to be flexibly organised in order to enable householders to orient their activities towards those of others and thus maintain the equilibrium. Thus, as we have seen throughout, certain routines emerge by virtue of which certain spaces are seen as 'belonging' to certain individuals at certain points in time when they use certain pieces of technology as we see from this following extract from a visit to one couple:

> M " ... Yeah but you do think of this room as being the relaxing room ... "
>
> S "Yeah I suppose that's true ... "
>
> M " ... because when I'm working in here ... sometimes I work in here to have a break from working next door, in the bedroom on and S wants to put music on and play the guitar or watch the television ... and he always has ... whoever wants to relax in here has priority and the person who's working has to leave ... "
>
> S " ... yeah that's true, because we have all the entertainment systems set up in this room ... so yeah I do see this as a room to relax in ... and do all my work in the bedroom ... "
>
> Such 'rules' have:
>
> M "emerged explicitly ... I mean it's not like we sat down and said 'Oh, this is what it's going to be like, but then ... I mean [to S] you tend to make rules quite explicitly, so you say 'I will not come into the bathroom when you're in the bathroom, don't come in when 'm in the bathroom'. You said 'This room is for entertainment, I have priority at this moment' ... I mean you said that whereas I tend to do it a different way ... I tend to be bolshie or you know, slam doors ... things like that ... so it's not quite as explicit ... I think [to S] you formulate things a lot better than I do"
>
> S "Yeeeah, but I'm actually, sort of, willing to compromise a bit you know ... this makes me sound like a bloody ogre!" [Laughs]
>
> M "Well look for example, I don't think S is quite as tidy as I am ... and just through ... constant tidying, S is now as tidy as I am, because he knows that if I don't, he doesn't do it, then I will, and sometimes he doesn't want me to tidy up! So he doesn't me to do something different from what he's doing so he'll tidy up before me ... do you see what I mean?"

Once again we do not wish to imply that all these sets of activities are scripted and slavishly adhered to, of course the actions of others are interpreted in the light of whatever contingencies might arise and activities, routines, households and domestic technologies are duly reconfigured to continue to afford coordination. Indeed here we come to the nub of the matter, since the most successful of domestic technologies interleave successfully with this social organisation and, in allowing users to establish their own sets of usage practices - to organise themselves, as it were - can support a range of uses in a range of household situations, allowing for the routine distribution of action, interaction and associated technology use throughout the house.

7 Lessons for the Development of Cooperative Buildings

Even when technology is the environment - i.e. in the "roomware" of cooperative building - this technology will still find its character and succeed or fail in the actions of those making use of that technology. The need to allow systems to be adopted and made of utility to users is not a particularly new lesson to those involved in the development of interactive systems. For example, the need to attend to these details feature regularly within the CSCW literature. However, in the case of realising future cooperative buildings the problem is amplified as the building must as part of its design brief allow significant redesign in use as people literally design and realise their own domestic environments.

The nature of our studies continually highlighted the situated nature of the every activities within domestic environments. People undertook particular actions within domestic environments often precisely because of the nature of these environments. Houses did not offer a spare bedroom or the living room was a particular shape or the house could not be further extended. Understanding the highly contextual nature of these requirements means that we must look closely at developing an understanding of the nature of activity within the context of the physical places it takes place in. Understanding these activities and developing design guidelines requires an examination of the relationship between technology and space within cooperative buildings. In this paper we have suggested that the use of ethnographic studies of environments such as homes offers the possibility to develop a set of design guidelines for future cooperative building developers.

In supporting the ability of the future inhabitants of domestic environments to make best use of cooperative buildings the variability, diversity and distributed nature of activities in the home must be realised. People undertake different activities throughout the home based on their chosen use of the home and often exploit the nature of space. Spaces are designed within peoples homes in order to support particular activities and the overloaded nature of domestic environments is such that these spaces are seldom dedicated to single purposes. Rather they are actively reconfigured and used at different times for different purposes. So a single room may at different times move from being a study, to a playroom, to a guest bedroom, to a games room, given the particular demands of those who inhabit the home. Future cooperative building technology must seek to promote the use of technology as part of the core aesthetic fabric of the environments. In doing so it is no longer enough to think of the technology in cooperative buildings as the product of a design process rather we must consider it as been the tools of design for the environment itself as it is inhabited and used.

In understanding the need to support the design of space within technologically loaded buildings such as future domestic environments we must not overlook the quality of the space and the role of technological artefacts in determining this quality. The aesthetic quality of spaces are central to people defining an environment as their own and the adoption of technology in defining this space is important. Televisions, hi-fi and videos are all placed in particular locations to improve the aesthetics of rooms, lighting is modified to set particular moods and often the exact nature of technology is determined by its fit to a particular style. In fact, in most of the homes we studied a clear distinction existed between computers and other technology in the home that was considered part of the furniture. The need to reconsider computer technology as an artefact with a clear and defined set of aesthetic properties emerges from a consideration of computers as part of domestic environments and we would claim this extends to any future consideration of computer systems in cooperative buildings.

As a final observation of our work we would like to emphasis the way in which homes are made to work by the actions of those managing the activities within them. Much of the skill of living successfully within environments is managing the daily milieu of activities within the confines of the space available. The fact that a space can be adopted and used for a variety of purposes is central to the ability of inhabitants to interleave these different activities. A major issue in the development of more sophisticated cooperative buildings is the placement of different technology within the building. A particular dedicated functionality within a technological artefact often attracts action into the space in which the technology is located. When a piece of technology is bound to a particular space - i.e. is the space - this limits the use that can be made of the space and can directly affect the ability of inhabitants to make the building work for them. What this suggests is that in the development of cooperative buildings we must be careful in the level of commitment we make in constructing dedicated spaces. The higher the cost in modifying and rearranging the space the more stresses it is likely to bring to those who inhabit it in undertaking their daily routine activities. This stress is most prominent in the case of domestic environments where the notion of dedicated purpose and function is less obvious than in ,for example, control rooms. However, we believe the lesson is worth remember for any cooperative building open to use for a range of different purposes.

References

1. Hirsch, E. (1992). The Long Term and Short Term of Domestic Consumption. In: R. Silverstone and E. Hirsch (Eds.) *Consuming technologies : Media and information in domestic spaces*. London: Routledge.
2. Hobson, D. (1982). *Crossroads: the Drama of a Soap Opera*. London: Methuen.
3. Lull, J. (1981). *Inside Family Viewing: Ethnographic research on television's audiences*. London: Routledge.
4. Mackay, H. (1995). Patterns of Ownership of IT Devices in the Home. In: N.Heap et al. (eds) *Information Technology and Society*. London: Sage.

5. Moran, R. (1993). The Electronic Home: Social and Spatial Aspects. *1993 Report of the EC's European Foundation for the Improvement of Living and Working Conditions* (Luxembourg: Office for Official Publications of the European Communities).
6. Morley, D. (1980). *The Nationwide Audience*. London: BFI.
7. Morley, D. (1986). *Family Television.* London: Comedia.
8. Silverstone, R. (1994). *Televison and Everyday Life.* London: Routledge.
9. Venkatesh, A. (1996). Computers and other Interactive Technologies for the Home. *Communications of the ACM,* 39, No 12.

Author Index

Keyword Index