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Disciplinary and Semiotic Relations across Human-Computer Interaction

Ph.D. Thesis [1]

by

Luiz Ernesto Merkle [2]
Graduate Program in Computer Science

Submitted in partial fulfilment
of the requirements for the degree of
Doctor of Philosophy

FACULTY OF GRADUATE STUDIES
THE UNIVERSITY OF WESTERN ONTARIO
London, Ontario
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[2] Centro Federal de Educação Tecnológica do Paraná, Academic Department of Informatics

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Leon Surette

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Luiz Ernesto Merkle
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Abstract

This thesis discusses the multifaceted nature of Human-Computer Interaction through dimensions associated with disciplines in the sciences and engineering (information technology), the social sciences (people and society), and the arts and humanities (interaction and communication), and proposes a three-dimensional conceptual framework. The proposed framework is a three dimensional conceptual chart in which disciplinary relations can be visualized and explored. It is is used to chart the historical disciplinary boundaries of both informatics and HCI and their expansive or retractive tendencies, showing a chasm between Informatics' and HCI's theories and their actual footprints. This chasm is a motivation for an in-depth exploration of a small part of Peirce's work, the foundations of Semiotics.

The thesis structure includes topics across several disciplines, shifting from an exploration of the narrowing tendencies of Informatics (mostly product driven), passing through the broadening goals of HCI and Software Engineering (mostly human and management driven, respectively), and finally reaching the foundations of Peirce's Semiotics (necessarily ethically and esthetically driven).

Abstract relations are fundamental to a deeper understanding of Peirce's work, including semiotics. However, consensus on Peircean sign relations has been achieved neither in semiotics nor in its applications to informatics, being often in contradiction to it. In order to establish solid foundation between HCI and Semiotics, this thesis concludes with a systematization of the structure of Peirce's sign relations with the aid of tools developed in Informatics, stressing their relational and open characteristics. In particular, it discusses sign relations and derived categories as mathematical lattices. Multi-dimensional Hasse diagrams are introduced and used to structure and visualize both sign relations and relations among their categories. Existing diagrams are shown as particular cases of the proposed solution, illustrating its expressiveness.

Keywords: Design, Process Models, Curricula Recommendations, Human-Computer Interaction, Informatics, Interdisciplinary Relations, Peirce, Semiotics, Sign Categories, Classes of Signs, Sign Relations

saber é pouco	to know is a little bit
como é que a água do mar	how is that the sea's water
entra dentro do coco?	gets into the coconut?

Paulo Leminski[3]

It is good, at certain hours of the day and night, to look closely at the world of objects at rest. Wheels that have crossed long, dusty distances with their mineral and vegetable burdens, sacks from the coal bins, barrels, and baskets, handles and hafts for the carpenter's tool chest. From them flow the contacts of man with the earth, like a text for all troubled lyricists. The used surfaces of things, the wear that the hands give to things, the air, tragic at times, pathetic at others, of such things – all lend a curious attractiveness to the reality of the world that should not be underprized.
In them one sees the confused impurity of the human condition, the massing of things, the use and disuse of substances, footprints and fingerprints, the abiding presence of the human engulfing all artifacts, inside and out.
Let be the poetry we search for: worn with the hand's obligations, as by acids, steeped in sweat and in smoke, smelling of lilies and urine, spattered diversely by the trades that we live by, inside the law or beyond it."

Pablo Neruda.

from "*Toward an Impure Poetry*"[4]

---

[3] From Paulo Leminski. "*La Vie en Close*", Ed. Brasiliense. 1991

[4] Pablo Neruda. "Pablo Neruda Five Decades: Poems 1925-1970", Grove Press. New York. NY. USA. page xxi. 1974

to Zizito

and

Marinês

Acknowledgements

I came to the University of Western Ontario (UWO) to pursue my doctoral dissertation because my research interests were deeply entwined across phenomena related to cognition, design, and semiotics. Before I arrived, U.W.O. had an active Centre for Cognitive Science. In the Department of Computer Science, research on Software Engineering and Artificial Intelligence were being carried out. My thanks to my initial contacts: Prof. Mike Bauer, who works on distributed systems and softwaie engineering, was my first contact; and Prof. Robert E. Mercer has been my supervisor since I was applying for a CNPq scholarship.

My interests on engineering design as communication date back to my Electrical Engineering undergraduate course which had an emphasis on electronic and telecommunications. Since then, I have been reflecting on the intersection between semiotics and technology design, always in the light of the cognitive sciences, and on the test bed of informatics. Despite a possible resemblance with communication and engineering development, the communities that studied semiotics and software design were, despite a few exceptions, like oil and water. Oil and water are difficult to mix, but not impossible. Other components can be added to stabilize the mixture.

I would like to thank UWO for scaffolding an open and rich environment to foster interdisciplinary work such as the one I have pursued in this dissertation. In particular, I would like to specially thank my supervisor, Robert E. Mercer, for hosting and supporting my work and my dreams across an area that is not well-established or even recognized within the traditional realm of the discipline of computing.

One of the fields that is in the intersection between software design and cognitive science is Human-Computer Interaction (HCI). Upon my arrival at UWO as a graduate student, there was basically no research out Human-Computer Interaction being carried out at the university. I would like to thank Jacquelyn Burkell (Information and Media Studies, UWO), Ian Kerr (Law and Information and Media Studies, now at the University of Ottawa), Peter Denny (Psychology, UWO), Robert Barsky (English, now at *Université du Québec Montréal*), Roy Eagleson (Electrical Engineering, UWO), Thierry Belleguic (French, now at the *Université Laval*), Nazim Madhavji (now at the University of Otago, New Zealand), and Leon Surette (English, UWO) for the informative discussions we had.

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Contents

List of Tables

List of Figures

Preface

Information technology is deeply related to literacy and numeracy, enabling people to communicate, to interact with others and with the world in proactive, reactive and mediated ways, to intervene in the world they live. Information Technology affects society, for better or worse. The associated emergence of new professions, occupations, areas of expertise, research topics, merchandise, as well as the transformations of people's daily lives (either because they have access to such technologies, or because they do not) is not necessarily recent, but awareness for these issues have increased across the turn of the century.

Fields in Information Technology, such as computer engineering, computer science, and information systems are recognized and established within academic, industrial, commercial, and governmental institutions. Nevertheless, what was new and emergent a while ago became traditional and consolidated. Although communities in these fields have helped to overthrow the previously established order, the actual cultural transformations went beyond their niches of expertise. However, it is not possible to remain as such. There is a crevasse between the way Information Technology is woven across societies and the way it is understood within the same professions that have developed it. While computers are deeply transforming communication, the main theoretical frameworks still construe computers as isolated abstract machines.

These fields have identities linked with innovation, entrepreneurship, leadership, to mention a few, but no longer determine alone the blueprints of Information Technology. The transformations that these now orthodox communities helped to foster are deeply echoing across their own foundations and current practices, questioning their professional disciplinary niches. It is possible to understand professions across Information Technology as completing a first cycle, a cycle of initial consolidation, of initial recognition. But this has only been a first one among the many yet to be undertaken.

The more and less traditionally involved communities will have to transform their practices, their theories, and their praxis according to their social and ethical rights and responsibilities. As more and more fields emerge to fill the gaps left by traditional domains of expertise, professionals, researchers, educators, and policy makers, who have their lives structured around certain world views, face the challenge of being on the crossroads between the new and the old. The further development of Information Technology demands an openness and an integration of the computing artifacts with their context.

The mentioned crevasse is slowly being challenged and bridged, but changes are simultaneously fantastic and threatening. They are fantastic because they show how fruitful the technological interventions have been across societies. They are threatening because this same fruitfulness appears to dislodge some of its forerunners, mostly if their traditional prescriptions turn to be ineffective in current situations or have unexpected consequences. The emergence of new fields and new responsibilities put traditional identities into question, triggering responses that go from the most revolutionary to the most reactionary.

For example, the relation between people and technology, in its many scales and time frames, has indeed attracted interest on issues that have remained dormant during the consolidation years of Information Technology. Similar interests have nurtured the development of fields such as: Human-Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW), with their emphases on people's activities; Computer Semiotics and Organizational Semiotics with a focus on meaningful design; Software Engineering and Organizational Learning with foci on the management of technology production and maintenance; Electronic Commerce, Distance Education, and the Social, Ethical, and Legal aspects of technological interventions and their critical appraisal. A link between the study of computers and the study of language is not new. Throughout the history of Information Technology there are many cases in which the cross-pollination between numeracy and literacy, and between computing and communication has been present. It is enough to attempt to imagine a hypothetical computer science developed without computer languages. In order to imagine a similar scenario, we would have to travel back half a century or more to a time in which computers were not "programmed", but wired, and also forget earlier related work on algorithms and automation.

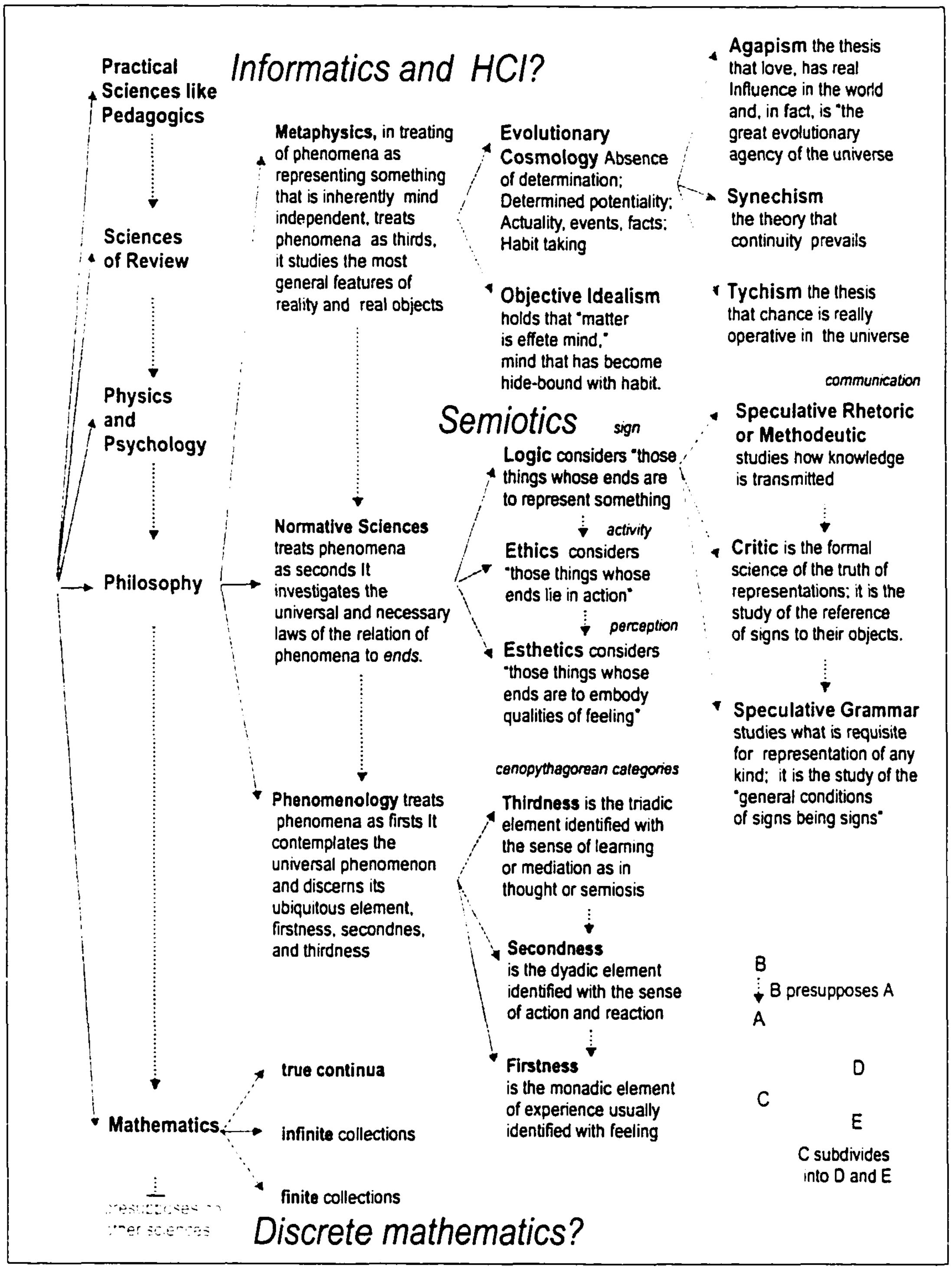
Indeed, the link between computing science and linguistics lays at the same venue as the above mentioned crevasse. Following a legacy that dates back to the strong link between linguistics and formal languages, the disciplinary barriers that separate developers from users, and closes the computer to the outside world is not only in close consonance with the study of language as structure, but also in contradistinction to the study of language as activity, as utterance, as use. As language, Information Technology is meant to be effective in use, and not only as form.

The thesis is intended to to give a small contribution to a broader understanding of "Informatics" as a multifaceted open discipline, one that is committed to several disciplines, and may involve a myriad of other ones. I will use the term Informatics to stand for this heterogeneous field still in construction, which in my perspective includes current disciplines such as Information Technology and Human-Computer Interaction (HCI).

As a path towards a broader understanding of Informatics, the thesis explores the nature of HCI and its disciplinary ecology having part of Charles S. Peirce's work as a backdrop. Peirce's systematic philosophy illustrated in Figure 1 spans across a scope broader than most approaches that study language and communication.

Figure 1 uses an arborescent diagram to illustrate both the segmentation of Peirce's systematic philosophy and what each branch presupposes. For example, Semiotics (also called Logic) presupposes Ethics and Esthetics. That is not necessarily the case in Semiotics as developed throughout the twentieth century by all of Peirce's followers and by other schools of thought. Scholars and scientists have the tendency to stratify, pigeonhole, and linearize their disciplines as if they were unconnected, and this can be identified both in Informatics and in Semiotics.

Figure 1 graphically depicts a description of Peirce's evolutionary philosophy writ-



Metaphysics, in treating of phenomena as representing something that is inherently mind independent, treats phenomena as thirds, it studies the most general features of reality and real objects

Evolutionary Cosmology Absence of determination; Determined potentiality; Actuality, events, facts; Habit taking

Agapism the thesis that love, has real Influence in the world and, in fact, is "the great evolutionary agency of the universe

Synechism the theory that continuity prevails

Objective Idealism holds that "matter is effete mind," mind that has become hide-bound with habit.

Tychism the thesis that chance is really operative in the universe

Normative Sciences treats phenomena as seconds It investigates the universal and necessary laws of the relation of phenomena to *ends*.

Logic considers "those things whose ends are to represent something

Ethics considers "those things whose ends lie in action"

Esthetics considers "those things whose ends are to embody qualities of feeling"

Speculative Rhetoric or Methodeutic studies how knowledge is transmitted

Critic is the formal science of the truth of representations; it is the study of the reference of signs to their objects.

Speculative Grammar studies what is requisite for representation of any kind; it is the study of the "general conditions of signs being signs"

Phenomenology treats phenomena as firsts It contemplates the universal phenomenon and discerns its ubiquitous element, firstness, secondnes, and thirdness

Thirdness is the triadic element identified with the sense of learning or mediation as in thought or semiosis

Secondness is the dyadic element identified with the sense of action and reaction

Firstness is the monadic element of experience usually identified with feeling

Figure 1: **Peirce's Systematic Philosophy:** based on the introduction in Peirce et al. (1991)

ten by the editors of a recent collection of his writings (Peirce et al., 1991), which also included the following comment:

> Peirce's philosophy is thoroughly systematic - some might say it is systematic to a fault. Central to his system is the idea that certain conceptions are fundamental to others, those to still others, and so on; so that it is possible to analyze our various theoretical systems (our sciences) into a dependency hierarchy. At the top of this hierarchy (or at the base if we envision a ladder of conceptions) we find a set of universal categories, an idea Peirce shared with many of the greatest systematic thinkers including Aristotle, Kant, and Hegel. Peirce's universal categories are three: firstness, secondness, and thirdness

I have structured this thesis in two main interrelated parts. Part I, which includes Chapters 1, 2, and 3, explores the cultural ecology of Information Technology and Human-Computer Interaction. Part II, which includes Chapter 4 and the conclusions, explores the problem of order in sign relations and derived categories, and discusses future work, respectively.

Within Figure 1 I would locate Informatics and HCI as a practical science, located at the top of the diagram. For Peirce, practical sciences, such as pedagogics, presuppose all other fields. This is in agreement with the fact that HCI presupposes psychology, for example. In its current forms, HCI does not always presuppose knowledge transmission or mediated activities.

Part II, however, would be located mostly at the bottom part of Figure 1 and deals with the relational structure of signs and categories of signs. In between top and bottom, there is a huge crevasse that needs to be explored more deeply if one intends to develop semiotic foundations for HCI/Informatics. Without being comprehensive, I have attempted to develop this thesis in close resonance with Peirce's rationale, which does not assume that Peirce was completely right.

The thesis title is a reference to these two extremes. On the one hand the thesis explores the still et loose disciplinary relations that structure the field of Informatics/HCI as an heterogeneous arena. On the other hand it explores the relations of order that structure the core elements of its foundations, but always having Peirce's related work on the horizon. I should remark that as Informatics/HCI matures their horizons will also change.

Chapter 1 explores the development of Informatics' disciplinary diversity. This exploration includes topics such as the specialization of Informatics into just a few disciplinary branches. This specialization increased the depth of certain subjects at the expense of loosing part of Informatics' initial breadth. In the proposed conceptual framework, which is completed only in Chapter 2, disciplinary segmentation is visualized with the aid of divergent constellation of interests that have consolidated different but not necessarily nonintersecting niches of expertise. Some other related areas focused on what was out of focus in Informatics, but they are not usually listed as part of it.

Chapter 2 explores Human-Computer Interaction as an example of such a divergent disciplinary force. In both Chapters 1 and 2 information gathered from curricula recommendations and professional opinions illustrates how these fields have narrowed their scope to small disciplinary niches, leaving spaces for other fields to develop. The development of Computer Supported Cooperative Work in contraposition to HCI is an example. However, models of HCI's subject matter have not been comprehensive enough to capture this and other diverging tendencies. With this comprehensiveness as a goal, a multi-faceted model of HCI's cultural ecology is proposed and briefly exemplified. An ecological approach that describes disciplinary niches and their relations is intended to foster both disciplinary diversity and openness towards what is different. The description of the "cultural ecology" of an area involves the demarcation of the scope and depth of its disciplinary niches, which includes the identification of interfaces, barriers, and strength of connections between them, awareness for unexplored regions, and so on. In this sense, the proposed model enables the mapping of actual or aimed limits and foci of the disciplines or areas that currently compose a certain field. The model is intended to provide a more detailed description of the current complexity found across HCI and Informatics, at least considering the perspective adopted here. For example, with aid of this multifaceted model, it is possible to visualize the decrease in scope that went from organizations to individuals when the popularity of personal computers surpassed mini and mainframe computers (data processing). This enables a more complete, but not yet comprehensive, account of their history.

The proposed model is structured within dimensions associated with technology, people, and interactions. It has been developed in light of Peirce's work. Most approaches in informatics still model computers as closed isolated machines. If mapped into Peirce's philosophy this would correspond to mathematics as finite collections of elements.

I am aware of the dangers of working between disciplines. The following examples are intended to acknowledge that the development of informatics/HCI can be mapped as a trajectory across Peirce's philosophy. In other words, Peirce's work is a suitable candidate to scaffold theory building in HCI/Informatics. When one talks about the phenomenology of user-oriented or user "friendly" friendly systems there is reference to feeling, which would be almost at or at the level of firstness (feeling), respectively. Artifact human-centeredness as developed in HCI, is usually restricted to individual computers and individual users. Norman's gulfs of execution and evaluation would be at the level of secondness (action and reaction). Approaches that emphasize the role of technology as mediation, such as Computer Mediated Communication would be mapped around thirdness (mediations in thought).

The trajectory of genres of interaction also drifted from the simple but "abstract" level of command languages (thirdness) past the "concrete" level of direct manipulation (secondness). Currently, there are mixed genres. Similar analysis could be carried out at the level of Peirce's Normative Sciences, and different approaches could be mapped according to the common focus on perceptions, activities, or representations. With the danger of being repetitive, I should remark that such a classificatory approach easily enters into a dead end. The importance of Peirce's philosophy is its relational character. Peirce's categories are not existential. When one classifies a certain sign into a certain category one is saying that it is of a certain kind at that moment and situation. Basically it is in a certain state, but at another moment it can be classified within another category or state. In this sense they can be an interesting framework to explore thought as action and design as interaction.

Chapter 3 further complements the conceptual framework with the notion of process. It emphasizes the dynamic, open, relational and non-periodic nature of computational and communicative processes. It also illustrates how both interaction and process models used across HCI and Software Engineering have restricted a scope, and are often reductionist. The waterfall, the spiral, and prototyping design process models have different constellations of interest, varying in foci and breadth. Overall, they usually emphasize development rather than both development and use. The process model is intended not to be prescriptive in the sense of scheduling design activities. Nevertheless, it prescribes a space for possible design activities which can chaotically oscillate between activities usually associated with development and use. At a glance, the process model introduced in this chapter seems to be in close consonance with Peirce's Evolutionary Cosmology, in which absence of determination presupposes habit. Further research needs to be carried out on this subject.

Chapter 4, the sole chapter in Part II, has a different approach. The thesis has until this point adopted a broad but somewhat shallow perspective considering Peirce's philosophy. The reader interested in HCI approaches such as distributed cognition, semiotic engineering, computer semiotics, language/action, and theory of activity may be disappointed that I have not explored these approaches in more detail. With varying emphases on purposeful perception, action, and representations, these approaches would be at the level of the normative sciences and would presuppose Peirce's phenomenology. Chapter 4 explores Peirce's concepts of signs and the associated sets of derived categories. In Peircean Semiotics (logic) a sign relation is triadic, but it can be refined into a decadic one. Categories of signs are obtained from the correlation between a sign relation and the cenopythagorean categories, the subject of Peircean phenomenology. The full development of a Peircean semiotic foundation for HCI would demand at least the consideration of issues that span the level of how knowledge is transmitted (Speculative Rhetoric). As suggested by the diagram, full foundations for HCI/Informatics would demand the consideration of the whole diagram. Both options are too broad to be carried out in a Ph.D. thesis.

Consequently, I focused on the most fundamental and narrow topic within Peirce's related work, which deals with finite collections of elements. With that choice, I was still able to envision the breadth of the involved foundations, leaving the door open to future research, but was able to deepen its most fundamental core. The chosen scope coincides most with the theoretical realm of Computing Science, in which several formalisms and structures have been developed to explore relations between finite sets of elements (data structures). In it, the relational structure of both sign relations and derived categories are understood as lattices, not a completely novel idea, and visualized with multi-dimensional Hasse diagrams. Several diagrams found in the literature turn out to be special cases of the proposed solution, facilitating their comparison and illustrating its generality.

This thesis represents only a first small step towards the development of a full-fledged conceptual framework for HCI/Informatics. It was not intended to be comprehensive, but rather to foster both an encompassing overview of the involved issues and more solid foundations.

I would say that professionals in Informatics and HCI, broadly understood, have a challenging task ahead. Their perspectives have grown limited but are claimed to be universal, turning other fields into mere applications. It is still a product driven discipline. Let Informatics and Human-Computer Interaction grow. Let it be driven by the way people live.

Curitiba, Paraná, Brazil

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Part I

The Cultural Ecology of Informatics and Human-Computer Interaction

Chapter 1

Informatics Disciplinary Diversity

Caminante, son tus huellas
el camino, y nada más;
caminante, no hay camino,
se hace camino al andar.
Al andar se hace camino
y al volver la vista atrás
se ve la senda que nunca
se ha de volver a pisar.
Caminante, no hay camino,
sino estelas en la mar.

Wayfarer, the only way
is your footsteps, there is no other.
Wayfarer, there is no way,
you make the way as you go.
As you go, you make the way
and stopping to look behind,
you see the path that your feet
will never travel again.
Wayfarer, there is no way -
only foam trails in the sea.

Antonio Machado,
from "*Campos de Castilla*", from the poem "*Proverbios y Cantares*"[1]

---

[1] Proverbs and Song Verse, translated by Alan S. Trueblood (Machado, 1982, p 143)

1.1 Introduction

A myriad of new disciplinary areas related to the art, the science, the technology, and the politics of processing information have emerged during the late twentieth century. Peter Denning has recently called this broad field Information Technology (Denning, 2000a,b, 2001). I use the term "Informatics" to denote this area.[2]

Informatics has been a field in transformation. It is usual to describe Informatics related disciplines, such as the ones focusing on computing and information systems, as being in a rapid and constant expansion, as having an identity grounded on a constant innovation, and as being the foundations for an envisioned social revolution. The expanding tendencies of informatics have also been supported throughout its development by abstractions such as Moore's law, which predicts that computer will be always faster, by the fast paced growth of the World Wide Web, and by their joint use of communications technology. Suddenly, the products of informatics transformed the way people interact across time and space. It has not been much questioned, however, how the disciplinary profile fostered throughout its development has varied; at least by those who work in informatics.[3]

However, the widespread assumption that informatics is an ever expanding field does not correspond to the actual disciplinary variations found across its historical development. Indeed, the communities in informatics have narrowed their disciplinary

---

[2] The term "informatics" is not widely used in English speaking cultures to refer to computing and information related areas in engineering, science, and business. In English "informatics" stands mostly for the field of Library and Information Science, but its definition encompasses "the science of processing data for storage and retrieval". The terms *informatique* in French, *informatik* in German, *Informática* in Portuguese, and *informatika* in Russian varies, but they usually denote broader fields than does Information Science in English, including Information Systems and Engineering. See Coy (1997) for even broader definitions.

[3] The 2001 Informatics industrial downturn in U.S.A. has taken many by surprise, but not everybody. (Brown and Duguid, 2000, p 13), for example, have questioned if less power could not be more, depending on the technology. Christensen (1997) discussed innovative technology that has initial lower performance compared to established ones. It eventually overpasses them in performance due to their higher potential. See Chapter 3.

scope in order to deepen their foundations. It is not by chance that the "nerd" stigma has been haunting professionals in informatics for a while. In this chapter I explore how the disciplinary scope of informatics have been reduced until recently. Only recently, part of its initial breadth has been rescued. For example, during informatics' inception phase (1940s and 1950s), it had a higher disciplinary diversity than it was able to maintain during the sixties, seventies, and eighties. During this period, areas such as anthropology, linguistics, design, human factors, psychology, industrial engineering, and others were mentioned as contributing to the field. From that initial diversity, only some branches have been consolidated within the community, on fields such as computer engineering, computer science, and information systems. The rest became either dormant, remained on the outskirts of particular disciplinary branches, or developed elsewhere. Information science is an example.

As the related communities narrowed their foundations, the consequences of informatics across cultures have continued to expand. This has both created a gap between the fostered perspectives and the demanded perspectives. Currently, the traditional branches of informatics face the conundrum of disciplinary renewal. People either reflect on the boundaries of their fields and on their foundations, or these fields run the risk of losing the significance and the established role across societies.

The main contribution of this chapter and the next resides in establishing a ground on which Informatics' disciplinary diversity can be discussed. I propose a model in order to discuss Informatics' disciplinary diversity variations across its historical development. The research question behind them is not restricted to "what is information technology" or "what is Informatics". Instead, the research question encompasses "what have been the disciplinary relations that have helped professional activities in Informatics to sustain and develop their practices and when have disciplinary relations among distinct communities been fostered or avoided?" I make use of a set of historical data, including comparisons of individual opinions, development of professional associations, transformations of curricula recommendations, and several proposed definitions to illustrate disciplinary depth and breadth variations across history.

A set of disciplinary events and transformations took place across Informatics life-span. As Informatics' areas of expertise developed and explored niches, they not only matured, but also established a corresponding division of labor. For example, as computer science restricted its focus around software (theoretical or practical, as algorithms and programming), other groups focused their interests either on hardware or on systems. Throughout the process, unexplored gaps, abandoned niches, and reinforced barriers enabled the emergence, the maintenance, or the decay of disciplinary practices, old and new. Computer Engineering, Computing Science, Information Systems, Information Systems Management, and Information Science today are examples of traditional fields.

The recent diversification of Informatics has been accompanied by the emergence of a myriad of other areas of expertise. Human-Computer Interaction, Bioinformatics, Social Informatics, Software Design, Computer-Mediated Education, Law & Technology are examples of fields that are not traditional. These newcomers emphasize legal, communicational, managerial, organizational, cognitive, biological, and esthetic in conjunction with constructive and analytical approaches.

Many new fields lay outside previous disciplinary boundaries of science and technology, such as media studies, digital library science, and computer media design. The introduced novelty has been changeling professionals, educators, law and policy makers, and politicians, who have neither grounds nor background to decide in which direction to go, or in what or whom to invest.[1]

1.2 Disciplinary Diversity across History

The constellations of disciplines that contribute to Informatics vary across a large spectrum. During Informatics' historical development, the number of disciplines that were effectively part of the field varied, as illustrated by several lists grouped in Table 1.1. During the emergence of the discipline, the diversity was relatively high

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[1] Cultural and historical factors make it easier, for example, for a professional in the humanities to establish a link with Informatics, than the other way around.

[1954] Samuel B. Williams, president of the Association for Computer Machinery, stated that although the association had been interested in all phases of computing, it would on directing its efforts on "other phases of computing systems, such as numerical analysis, logical design, application and use," and programming. (Williams, 1954, p 3).
[1960] Douglas Engelbart mentioned "psychology, computer programming and physical technology, display technology, artificial intelligence, industrial engineering (e.g., motion and time study), management science, systems analysis, and information retrieval [as] some of the more likely sources" to contribute to the "art of doing augmentation research"(Engelbart, 1962).
[1963] Saul Gorn characterized Computer and Information Sciences as using concepts from "mathematics, philosophy, linguistics, psychology, engineering, management science, library science, etc." and as encompassing topics such as "programming systems, computer system design, artificial intelligence, information retrieval, etc." (Gorn, 1963, p 150)
[1968] In an ACM curricular recommendation (ACM-CCCS, 1968, p 153), the committee listed only three areas (computer science and similar programs, information science, and data processing) and chose to focus on computer science due to its large growth compared to other branches.
[1970] Peter Wegner (1970), made reference to three cultures: Computer technology, Computer Mathematics, and Computer Science. He defended computer science as a different branch from engineering and mathematics.
[1971] The ACM Curriculum Committee on Computer Education for Management clearly plotted the key roles within the lifecycle of information processing systems as being of the information analysts, systems designers, programmers, and operators (Teichroew, 1971, p 577).
[1984] The ACM-IEEE Computer Society Joint task force, whose objectives were program requirements and accreditation issues, listed (a)computer science and engineering (b) computer science (c) information systems (d) system analysis and (e) data processing as in the scope of the computing sciences (Mulder and Dalphin, 1984).
[1997] Michael Goldweber et al. listed sixteen disciplines as important to computing (Goldweber et al., 1997, page 101).
[2001] Peter Denning listed more than three dozen specialization areas related to the information technology profession (Denning, 2001)). Two years earlier, Denning mentioned only two dozen (Denning, 1999).

Table 1.1: **Disciplinary diversity across Informatics development**

as in the field of cybernetics, for example. During its consolidation, some topics have been slowly incorporated, and others have been slowly abandoned. In accordance, disciplinary links with other disicplines were tied, strengthened, loosened or untied, depending on the subject.

The field of Informatics became structured around some apparently autonomous disciplinary segments supported by a broader division of labor. Autonomy may be highly desirable and necessary, but it has its drawbacks. The resulting labor division and disciplinary segmentation was key to the development of the field as it is known today. As a few branches acquired an apparent autonomy, such as computer engineering, computer science, and information systems, some people in them also lost track or never learned about earlier links.

However, the cultural role of Informatics grew beyond its niche of expertise, and its theories and practices started to become insufficient to account for the richness of its consequences. Given the opportunity, other branches emerged, increasing the established disciplinary diversity. Currently, the field is in a transition period and no disciplinary dynamics has been stabilized yet. In Table 1.1, I list some examples of how professionals in Informatics view its disciplinary profile across the last fifty years. See Figure 1.1 for a qualitative illustration.

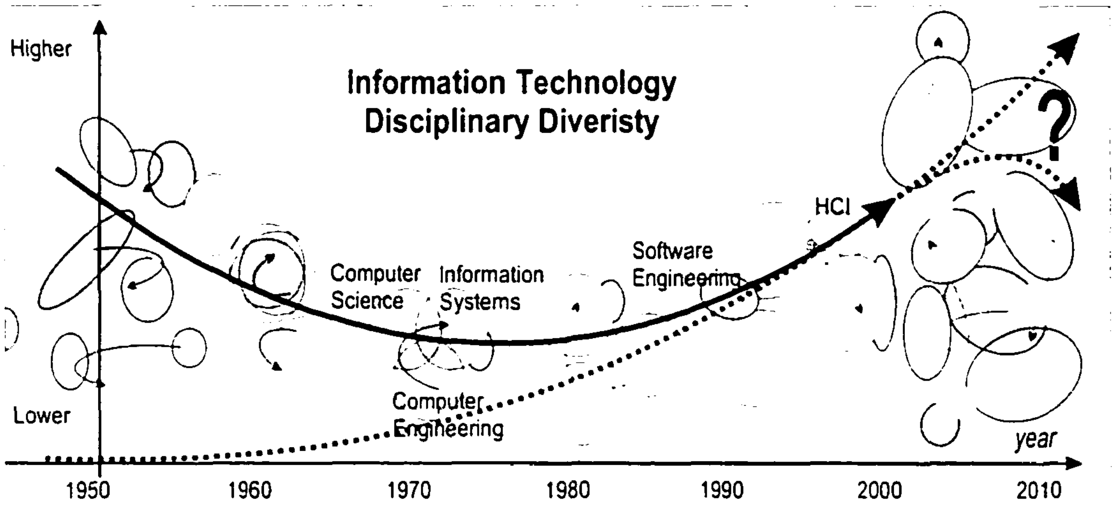

Figure 1.1: **Informatics historical variations in disciplinary diversity**

Overall, Informatics' disciplinary diversity has been reduced during its consolidation period and now it is increasing again. It is an open question how the communities in Informatics will structure their disciplinary diversity in the future: which fields or disciplines will play key roles in the next phases: which ones will decline or remain dormant for a still later future: and whether this pattern is cyclical or not. Currently, human-centered approaches are an indication that a link among the technological disciplines in Informatics can benefit from a cross-pollination with the human and social sciences.

It is undeniable that the involved communities have the responsibility to reflect on how Informatics will be reorganized. Their future depends on that. As Goldweber et al. said about disciplinary diversity in Informatics:

1997 Michael Goldweber, John Impagliazzo, Iouri A. Bogoiavlenski, A. G. (Tony) Clear, Gordon Davies, Hans Flack, J. Paul Myers, and Richard Rasala

Historical Perspective on the Computing Curriculum: Report of the ITiCSE'97 Working Group on Historical Perspectives in Computing Education (Goldweber et al., 1997, p 101)

It has been suggested that anthropology, applied psychology, computer science, cultural studies, economics, ergonomics, ethics, history, linguistics, management, mathematics, philology, philosophy, semiology, sociology, and politics are some of the disciplines relevant to computing. It is clear that we cannot do justice to this diversity in our educational programs by applying a single disciplinary perspective.

The recent increase in number of fields or disciplines that are related to Informatics is only an indication of the size of the challenge ahead. On what grounds is this diversity based, what is its current and its past state, how to compare them, and how to map disciplinary relations are issues that I explore in this and the next chapter. I have concentrated on the field of Informatics in this chapter. I begin with a description of the historical development of some professional associations related to the field of information technology. In the next chapter, I address the area of Human-Computer Interaction.

1.3 Development of Professional Associations

The objective of this section is to give a broad historical overview of some of the fields related to Informatics in order to build the foundations on which disciplinary relationships are discussed. I have chosen the history of professional associations because they have accompanied the field's history, and because their own history and their institutional names reflect actual practices.

Several professional associations related to the Informatics profession emerged during the twentieth century. Their development and maintenance have been and continue to be contingent on the interest or lack of interest of reasonably seized groups and on available resources.[5] In Figure 1.2, I depict the lineage of some professional associations in the United States. Figure 1.2 is organized according to the year in which the associations were founded, and according to a linear scale that goes from the hardware to the system areas.[6].

I have included the field of library and information science[7] in the diagram in order to illustrate a recognized area that is not currently viewed as within traditional Informatics. Many other areas or disciplines scaffold Informatics in their practices. From the perspective of disciplinary relations information science and other areas

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[5] The concept of Communities of Practice, as explored in Chaiklin and Lave (1993), Lave and Wenger (1991), Wenger (1999) was key to my understanding of a profession as a learning community.

[6] I understand that calling some domains "application areas" is biased and should be avoided. I avoid qualifying a area as an "application" of another one, because this practice has an axiology deeply rooted in the actual socioeconomic order in which Informatics division of labor is based. In the established axiology, "application" usually comes after "development". If application were characterized as "demand", the inverse would be true, and application areas would come first. I do not explore disciplinary power and status related issues in this thesis. But they are important to the ethical and social aspects of Informatics. See Bourdieu and Passeron (1990); Bourdieu (1991); Bourdieu and Wacquant (1992).

[7] People such as Vanevar Bush made important contributions both to what is known today as library and information science, as well as to computing. In the sixties, Saul Gorn referred to the newly emerged discipline as the Computing and Information Sciences (Gorn, 1963). Currently, Peter Denning classifies Information Science and Digital Library Science as information technology intensive disciplines (Denning, 2001).

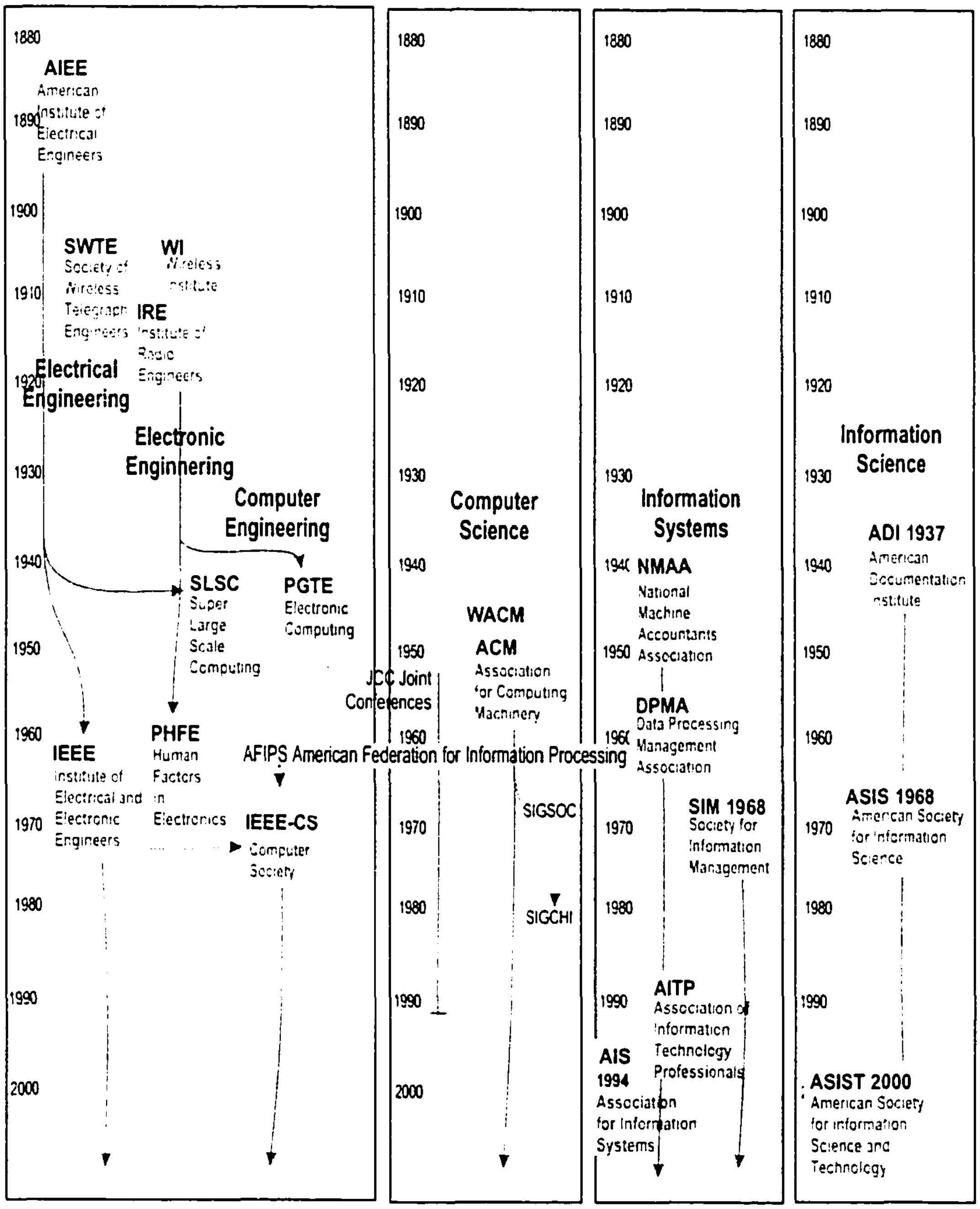

Figure 1.2: **Historical development of IT professional associations (1937-2000)**: The history of some IT professional associations is rich with processes of merges, splits, and transformations of identities. The change of the name of a professional association, for example, reflects part of the community's history and part of its aimed future. Some associations have never had their names changed, others have done it several times.

could both contribute to and receive contributions from Informatics.

In Figure 1.2 I depict the development of the major U.S. professional associations in Informatics during the twentieth century. Some professional associations sprouted from special interest groups of already established associations. Others resulted from the merge of different associations. For example, the Institute of Electrical and Electronic Engineers (IEEE) was formed by the merging of the American Institute of Electrical Engineers (AIEE) and the Institute of Radio Engineers (IRE). In Figure 1.2, I have included the special interest group on Human Factors in Electronics of the Institute of Radio Engineers, to illustrate a group in HCI that lived for a short period of time. Other associations sprouted from regional interest groups such as the Association for Computer Machinery (ACM), which started on the U.S. west coast and built an identity grounded in software and its abstractions. In the early 1990s, other associations had their professional identities transformed and their names updated as the Association of Information Technology Professionals and American Society for Information Science and Technology.

The field of Library and Information Science, for example, had professional associations organized internationally already in the nineteenth century. The trajectory of some professional associations in the field of Information Science at the national and international levels led their members to change their organizational identities and institutional names at several points during their existence. The most recent change was the inclusion of the word "technology" in the formerly named American Society for Information Science, as illustrated in Figure 1.3.[8]

The spatial organization of Figure 1.2 is important in this thesis because it exemplifies a first dimension on which it is possible to compare two or more disciplines, or two moments of a same discipline. In the diagram, a scale from hardware to systems

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[8] The objective of this example is illustrative and is intended to give the foundation for a subsequent historical analysis of curricular recommendations across Informatics as a whole. Several other associations could be included in a more systematic study if the objective were to compare their scope. For example, both the American Federation for Information Processing (AFIPS-1961-1990) and the American Association for Cybernetics had difficulties to sustain their inherited broad interests. The former was discontinued (AFIPS, 1964-90).

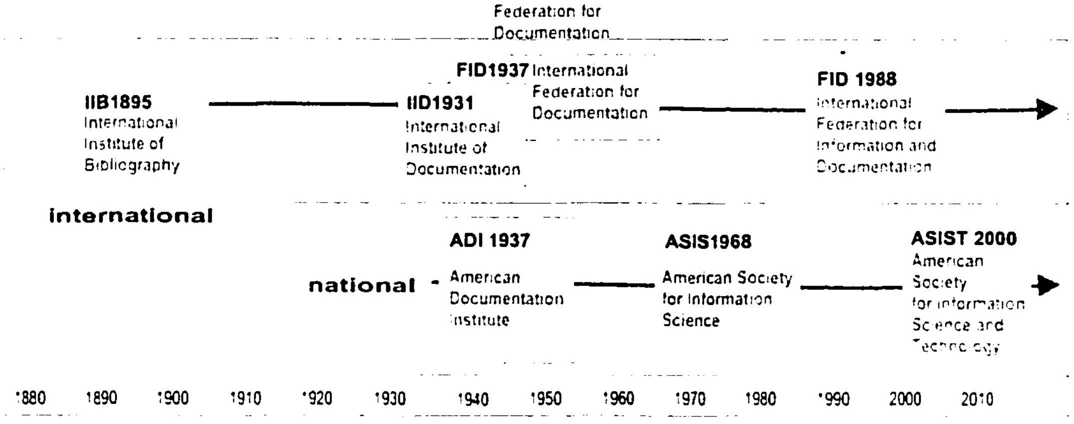

Figure 1.3: **Development of professional associations in Information Science**

organizes disciplines horizontally. I will refer to this scale as the technical dimension and scale, from now on. Variations of this dimension have been widely used in Informatics to describe its disciplinary segmentation. Different scales subdividing this dimension are possible. See Figure 1.4 for some examples.

In the remainder of this chapter I explore disciplinary variations with the aid of this technical scale. I should remark that this scale is not sufficient to depict comprehensively Informatics' disciplinary segmentation, and the relationships among the disciplines. For example, it is problematic to differentiate information systems from information management, software design from human-centered software design, distributed systems from the management of distributed systems, or even information science from library science.

Later in the dissertation, I introduce two other dimensions. A human one is introduced in this chapter, and a communicational one in the next. With the aid of these three dimensions, and their associated scales, I address disciplinary relations that include the social sciences and the arts and humanities.

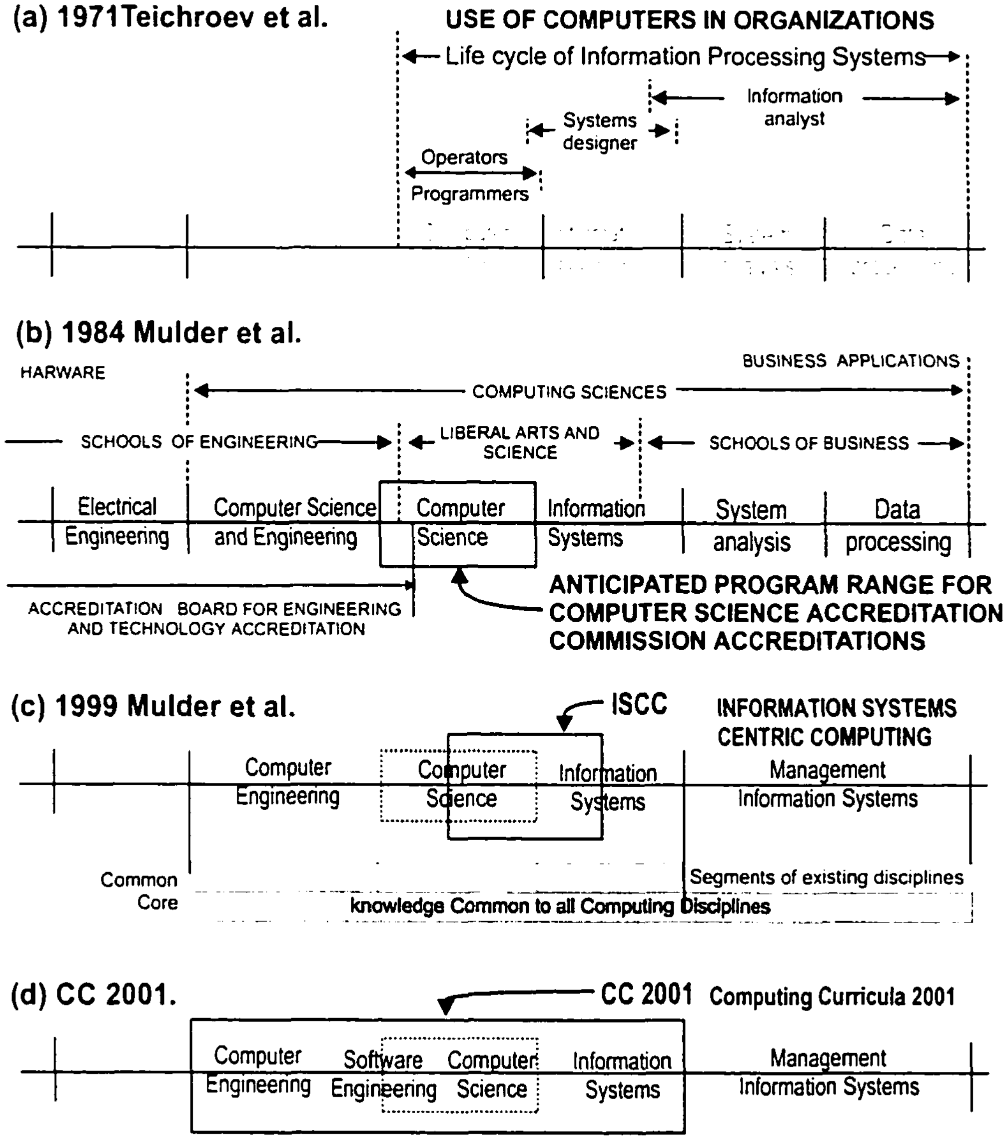

Figure 1.1: **Informatics disciplinary segmentation scales across history:** Some examples of disciplinary segmentation and their overlaps: (a) based on a diagram by the ACM Curriculum Committee on Computer Education for Management (Teichroew, 1971, page 577) (b) based on a diagram by the ACM-IEEE Computer Society Joint task force (Mulder and Dalphin, 1984, p 331) (c) based on a National Science Foundation report on Information Systems-Centric Computing Domain (Mulder and Lidtke, 1999) (d) based on Computing Curricula 2001 (IEEE-CS/ACM, 2001a, page 3).

1.4 Emergence of Informatics

The fields of Computer Engineering, Computing Science, and Information Systems have been recognized across academia, industry, commerce, government, and other cultural segments. In the middle of the twentieth century, there were no such disciplines. In 1954, a few years after the Association for Computing Machinery (ACM) was founded, its president, Samuel B. Williams, explained that the ACM was going to restrain its foci on what later became known as software and systems. He wrote in the first issue of the Journal of the ACM:

1954 Samuel B. Williams

The Association for Computing Machinery (Williams, 1954, p 3)

In 1951, the large engineering societies, AIEE and IRE appointed committees for the design and use of computing equipment. The Association has joined with them to form a joint AIEE, IRE, and ACM Committee. The JCC Committee has held meetings in Philadelphia, Pennsylvania; New York City; and Los Angeles, California. It is interesting to note that the attendance at the various computer meetings has grown from 78 in 1947 to 1500 in 1953.

The Association [for Computing Machinery] has become an important factor in the field of computing machinery. Until the engineering societies, AIEE and IRE, became sufficiently interested to struggle with the 'hardware', the Association provided a forum for all phases of the field. Now [1954] the association [ACM] can direct its efforts to the other phases of computing systems, such as numerical analysis, logical design, application and use, and at last, but not least programming."

Williams' explanation illustrates an historical watershed between two periods: a first period in which the American Institute of Electrical Engineers, the Institute of Radio Engineers, and the then recently formed Association for Computing Machinery were organizing joint conferences, for example, and a second period in which the IT community started to narrow down its interests in order to deepen its foundations.

Simultaneously, a disciplinary segmentation was being structured. An association that did not survive this segmentation process was the American Federation for Information Processing (AFIPS-1961-1990). It grew out of the organization of the joint conferences organized by the AIEE, the IRE and the ACM until 1951 (AFIPS, 1964-90).

The context in which Informatics was emerging was indeed very diverse. The field of Cybernetics, for example, was also emerging. Cybernetics' subject matter is focused on control and communication systems. Cybernetics is interdisciplinary and includes a range of topics that goes from the stabilization of sub-atomic particles to weather forecasting.[9] [10]

I should remark that in the period between the 1940s and early 1960s there was no computer science as it is known today. Even the name of the new field was yet to be defined. The communication, computing, and information disciplines emerged from a milieu at least as wide as the scope that cybernetics had in the nineteen fifties. Cybernetics was not the only discipline in the context that surrounded and supported the emergence of Informatics. Saul Gorn listed the contribution of several disciplines:

1963 Saul Gorn *The Computer and Information Sciences: A new basic discipline* (Gorn, 1963, p 150)

It is the belief of the author that a new basic discipline is emerging which might be called "The Computer and Information Sciences". This field makes application of concepts from the traditional fields of mathematics, philosophy, linguistics, psychology, engineering, management science, library science, etc. [...]

---

[9] See the "Transactions on Man, Systems and Cybernetics", an IEEE journal published since the late sixties, for examples.

[10] A series of conferences on "Circular Causal and Feedback Mechanisms in Biological and Social Systems" sponsored by the Josiah Macy, Jr. Foundation which took place between 1944 and 1953 illustrates cybernetics' interdisciplinary profile. These conferences have been chaired by Warren McCulloch, and were attended by people like Gregory Bateson (anthropology), Heinz Von Foersters (self-organization), John von Neumann (mathematics and computing), Margaret Mead (anthropology and social psychology), Norbert Wiener (mathematician and founder of cybernetics. See Heims (1991) and American Society for Cybernetics ASC (2000).

> Examples of general topics of study in it might be called programming systems, computer system design, artificial intelligence, information retrieval, etc. [... A] central topic in the new discipline would be the synthesis and analysis of mechanical languages and their processors.

Contrasting the situation in the mid-twentieth century, it is interesting to note that computer science and information science, as currently conceived, are considered to be very different disciplines. In the same article, Gorn listed some of the contents of "Computer and Information Sciences". The comments inserted are mine and they correspond to current areas.

> 1963 Saul Gorn *The Computer and Information Sciences: A new basic discipline* (Gorn, 1963, p 151).
>
> [*The Computer and Information Sciences include the study of any*] kind of signals which may be sensed, whether they be visual, aural, tactile, olfactory or motor [*multimodal interactions*]; or whether they be electrical, electromagnetic, mechanical, heat, or whatever [*multimedia interfaces*]. The arrangements of the signals may be in time, space, or both [*digital signal processing and image processing*]. The signals may be continuous or discrete [*control, discrete control systems, and robotics*]. Their interpretation may proceed purely sequentially or by an interlocking process with many partial interpretations going on simultaneously [*distributed systems*]. The arrangements of the signals may be linear, as on this page, or in multidimensional form [*hypermedia and multimeadia*], as in multicolored diagrams [*computer graphics, visualization*], tabular formats [*spreadsheets*], etc.

A strong disciplinary relation that has supported the emergence of Informatics was the cross-pollination between engineering and mathematics. Computer scientists went beyond the limits of both, and built the computing artifact. In one of the first ACM reports for curricula recommendations the committee wrote:

1965 Curriculum Committee on Computer Science ACM-CCCA

An Undergraduate Program in Computer Science - Preliminary Recommentations (ACM-CCCS, 1965, p 544)

The mathematician is interested in discovering the syntactic relation between elements based on a set of axioms which may have no physical reality. The computer scientists interested in discovering the pragmatic means by which information can be transformed to model and analyze the information transformations in the real world. [...]

Although much change has been accomplished within existing programs, such as mathematics and electrical engineering, there is a sizeable area of work which does not fit into any existing field. Thus, it is now generally recognized that this area, most often called Computer Science [...] has become a distinct field of study.

Table 1.2 and Figure 1.5 give a synoptic view of the curricula recommendations published in the United States context and some other related documents. In North America, computer engineering, computer science, and information systems were and continue to be generally housed in schools of engineering, science, and business, respectively. The relative apparent independence of each branch can be noted by the existence of parallel efforts present until the 1990s, when major joint efforts have started to be fostered and actualized.

The consolidation and the development of a professional identity does not happen in a vacuum. It demands a lot of effort and negotiation. It includes both novelty and stability. Novelty may be achieved by expanding the boundaries of a field, or by bridging existing fields, for example. Stability may be derived by deepening or complementing the profession's foundations in accordance with its scope.

When some communities in Informatics found or opened a niche for their interests, they consolidated these niches into disciplinary domains. In terms of disciplinary relations, the consolidation of a field is concomitant with the construction of its identity and subject matter. Therefore, there is a tendency to narrow the kind of phenomena that the field encompasses. In Informatics, it is possible to identify narrowing tendencies in the following quote from a 1965 ACM curriculum committee in computer science. The quote illustrates efforts in the field of computer science to concentrate

See (Wegner, 1970) for a view of the disciplinary culture in the early seventies which contrasted engineering, mathematics, and computer science.

In the engineering domain there are some key documents in the history of curricula recommendations. The National Academy of Engineering and the Commission on Engineering Education wrote a report in 1967 COSINE (1967). In 1977 and 1983 the IEEE Computer Society published model curricula in computer science and engineering (IEEE Computer Society, 1977; IEEE Computer Society, 1983).

These efforts were independent from the ACM, but in 1984 IEEE-CS and the ACM started to join efforts. In 1991 the two associations published Curricula 91 together (ACM/IEEE-CS, 1991). Since then, the two professional organizations have continued to work together, but maintaining their differences. In the 1990s, a recurrent discussion topic has been the definition and the delimitation of Software Engineering¿ The differences in perspective can be exemplified by the opinions of two researchers who have been giving constant contributions to Informatics, David L. Parnas and Peter J. Denning. Parnas (1998, 1999) reinforces boundaries by saying, for example, that Software Engineering is not Computer Science. Denning (1992) tends to undermine boundaries, aiming towards a broader education for engineering and computer science.

In the domain of Information Systems the key efforts have been developed since the early 1970s with the certification and registration of "business" programmers. In the eighties the Data Processing Management Association (formerly the National Management Accountants Association) published two sets of curricula recommendations, the DPMA 81 and the DPMA 86. During the nineties, members of the DPMA changed its name to "Association of Information Technology Professionals" and published five sets of recommendations.

IS'97 was developed as a joint effort of the ACM, of the Association for Information Systems (AIS), and of the Association of Information Technology Professionals (AITP). The Computing Curricula 2001 intends to bridge the field by giving recommendations in Computer Engineering, Software Engineering, Computer Science, and Information Systems.

For a comprehensive overview of curricula see Goldweber et al. (1997). The situation has not been much different in Europe. See Coy (1997) in Freksa et al. (1997) for a discussion on disciplinary choice and exclusion, among other related issues.

Table 1.2: **Curricula recommendations across Informatics development**

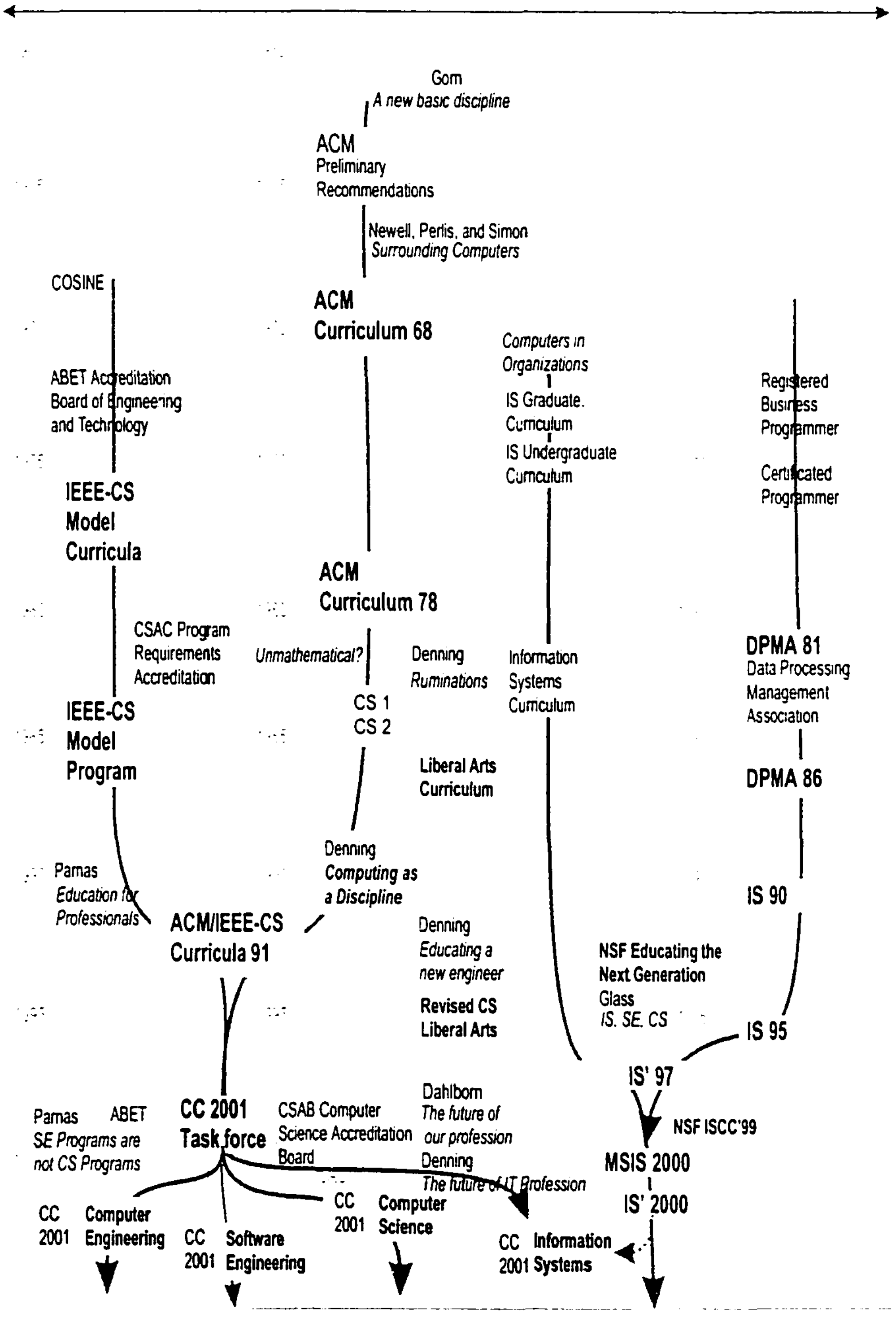

Figure 1.5: **Curricula recommendations in engineering, science, and business**

efforts and establish a distinct identity:

> 1965 Curriculum Committee on Computer Science ACM-CCCS
>
> *ACM Curriculum Committee on Computer Science* (ACM-CCCS, 1965, p 544)
>
> We [the committee] recognize that many needs are to be met in computer-related education; instruction in the use of computers as a tool is increasingly sought by students in the natural sciences, literature, medicine, management, etc.
>
> It has been suggested that the educational needs of those who will plan and design the computing and communication equipment of the future should be given special consideration. More specific thought will be given to the education of those wishing to prepare themselves for work in information retrieval, management science, the life sciences, and the behavioral sciences. However, the background of the students, the language appropriate to the subject, the pertinent exercises and examples, all differ, depending on the students' primary field. The Committee has chosen to direct its attention *first* to the student whose primary interest is in computer science. The committee solicits comment and criticism of the present report with the view of both strengthening the current recommendations and illuminating the relation between computer science and other fields of studies.

Simultaneously it was necessary to differentiate the field of computing from other ones such as mathematics and engineering, it was also necessary to establish a common denominator among its members, in order to support their practices and their identity. The computing artifact and its production process played this role for Informatics as a whole.[11] The definition of computer science[12] given by the 1965 ACM committee encompassed the following:

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[11] See Star and Griesemer (1989) and Star (1989) for the notion of boundary object, and Brown and Duguid (1994) for an alternative but related notion of border. Wenger (1999) referred to boundary objects and of brokers as a means of contact among distinct communities of practice.

[12] Overall the foci and boundaries of computer science's subject matter vary across its development. Definitions go from several phases of computing (1954), to automated information systems (1965), to phenomena surrounding computers (1968), to programming software and hardware (1978), to "what can be (efficiently) automated?" (1989), to all components of the Informatics profession (2001). I discuss some of these definitions in this chapter.

1965 ACM Curriculum Committee on Computer Science

ACM Curriculum Committee on Computer Science (ACM-CCCS, 1965, p 543)

[Computer Science] is devoted to the *representation, storage, manipulation,* and *presentation* of information in an environment permitting automatic information systems. [...] Some forms of information have been more thoroughly studied and are better understood than others; nevertheless, all forms of information – numeric, pictorial, verbal, tactile, olfactory, results of experimental measurement, etc. – are of interest in computer science.

In 1965, as the above definition reflects, the domains of Computer Engineering, Computing Science, and Information Systems were not clearly demarcated. This differentiation has been achieved only during the 1970s, when the relation between these fields have crystallized through their institutionalization as academic, industrial, commercial, and governmental organizations.

1.5 Consolidation of Informatics

In the 1960s computer science and other fields in Informatics were not fully recognized in the academic milieu. Although the criticisms were many, computer science and similar fields continued to develop steadily.

As Informatics developed further, its social implications and consequences increased, and its disciplinary diversity decreased. Throughout the consolidation process, most fields in Informatics slowly withdrew human and organizational issues from their subject matters, developing perspectives restricted to the artifact: centered on the artificial as if it were isolated from its context.

In some cases these issues remained in the domain of particular areas. For example, individuals or groups who were interested in people in computer science and in cognition/behavior ended up accommodating their interests in areas such as computer graphics, artificial intelligence, and project management. In information systems the segmentation structured the field into information systems and information systems management. Library and Information Science remained outside Informatics as an "application" area, and subdivided into information science and library science. With time, as the names indicate, each branch negotiated its disciplinary domain and its corresponding organization.[13]

As I have already mentioned, in 1954, the ACM president communicated that the association would focus on software and its use, withdrawing hardware to engineering. Reference to another disciplinary boundary was defended around thirteen years later. In 1967, Newell, Perlis, and Simon wrote a letter to Science, defending the field of computer science, explaining its differences, and discussing criticisms. In this letter, they gave a definition of computer science that restricted the subject matter of computer science to those phenomena "surrounding computers". In terms of disciplinary scope, their definition had a narrower scope than earlier ones:

1967 Allen Newell and Alan J. Perlis and Herbert A. Simon

Computer Science (Newell et al., 1967, p 1373)

In the definition, "computers" means "living computers" - the hardware, their programs and algorithms, and all that goes with them. *Computer science is the study of the phenomena surrounding computers.* "Computers plus algorithms, "living computers," or simply computers all come to the same thing - the same phenomena.(added italics)

Newell, Perlis, and Simon's definition still followed a heritage of systems thinking and cybernetics, which equate the artificial with the natural. During that period, the field was growing at a fast pace, but it neither had achieved recognition nor an established identity.

One year later, a more restricted scope can be identified in another definition. In Curricula 68, a subsequent set of curricula recommendations from the ACM, the committee grouped three major subdivisions that encompassed computer science's subject matter (ACM-CCCS, 1968, p 154-155):[14]

(a) "information structures and processes concerned with representations and transformations of information structures and with theoretical models for such representations and

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[13] Organizational change is not instantaneous and may have distinct patterns of development (Mintzberg, 1990; Mintzberg and Waters, 1985).

[14] These three items can be correlated with the later established computer science, computer engineering, and information systems.

transformations",

(b) "information processing systems" concerned with "systems having the ability to transform information. Such systems usually involve the interaction of hardware and software", and

(c) "methodologies" derived from "broad areas of applications of computing which have common structures, processes, and techniques."

The ACM committee chose to label the area Computer Science, instead of information sciences or data management (ACM-CCCS, 1968, page 153). They based their decision on the number of departments that had chosen such a label between 1964 and 1969. Other options were Data processing and Information Science. In contrast to the earlier definition the natural, and the "living" was abstracted away from its content.

The areas mentioned in Curricula 68 intersected with mathematics (numerical mathematics and simulation), engineering (process control), information systems (data processing, file management, and information retrieval), and other related areas, such as philosophy, linguistics, industrial engineering, and management. The 1968 committee considered them essential to balance computer science programs.

The still blurred 1960s computing artifact was clearly subdivided in hardware, software, and systems during the 1970s. This subdivision was accompanied by a disciplinary segmentation chain in which engineers build hardware, computer scientists write software, and information technologists deploy and maintain the resulting systems within organizations.

Ten years later, the ACM published another set of curricular recommendations. In the Curriculum'78, the committee did not give a definition of computer science, but it listed four groups of topics considered fundamental to computer science: (a) programming topics, (b) software organization,(c) hardware organization, and, (d) data structures and file processing. In terms of disciplinary relations, this definition enabled (a) a computer science focus on programming topics and software organization, (b) an interface with electrical engineering through hardware organization, and (c) an interface with information systems through data structures and file processing.

respectively. I should remark that Curriculum'78 has partially guided the establishment of many computer science programs across North America.[15]

1.6 Excess of Disciplinary Segmentation

During the 1970s the disciplinary segmentation stabilized on specialization having domains focused on hardware, software, and systems. Each specialization became reified across educational institutions and their enacted curricula, across industry and commerce and their organizations, and across governments with policies and resources.

The consolidated branches of Informatics became computer engineering, computer science, and information systems. They built identities connected to hardware, software, and systems, and they were usually housed in schools of engineering, science, and business, respectively.[16]

The process models that guided the development of computing systems reflect this subdivision. The waterfall product lifecycle, for example, is commonly depicted without a maintenance phase. This is in accordance with a disciplinary subdivision in which those who do the maintenance are professionals in information systems, and not in computer science.[17]

As time passed, educational and professional practices in these fields became increasingly insular. I should stress that the insularity is apparent in terms of disciplinary relations. It worked and it was indeed effective because it has been co-

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[15] Later on, Curriculum'78 has been criticized for its excess of emphasis on programming. What is usually not mentioned is that, although the core was very narrow and restricted mostly to software, Curriculum'78 had a course on Computers and Society. However, most universities never implemented it.

[16] This subdivision is not that simple. It is contingent on the university, industry, government, country, culture, and period in which it exists. Therefore, this categorization is questionable to delimit their boundaries, but it can be useful to identify their approximate center of interest and fostered boundaries.

[17] See Chapter 3 for a critical discussion on process models.

developed with a broader division of labor actualized by other segments.

The disciplinary subdivision was actually depicted graphically in a 1984 joint ACM and IEEE Computer Society report on program requirements and accreditation of computer science and engineering programs. In this graphic representation, as redrawn in Figure 1.4(b), the committee demarcated the domains of several specializations across Informatics. Of particular interest in Figure 1.4(b) are the intersection between engineering and the computing sciences, and the main schools in which the specialization were usually housed: engineering, science and liberal arts (which for the committee had the same scope), and business. It is also interesting to compare it with Figure 1.4(a) developed in information systems management in 1971.

With the advancement of Informatics people started to question the appropriateness of its disciplinary organization. Since the 1980s and 1990s, there have been several attempts to increase, or rescue, some of Informatics' initial breadth and resilience. For example, although Curriculum'68 had several courses in mathematics, Curriculum'78 did not have mathematics in its core set of courses. Its absence was immediately criticized (Ralston and Shaw, 1980; Ralston, 1984). Each set of recommendations was preceded and followed by a discussion within the involved community.[18]

The demand for professionals with a general understanding of informatics, but with a major in another discipline was not encompassed by either of its enacted disciplinary branches. Around the mid 1980s, a movement towards liberal arts degrees in computer science appeared (Gibbs and Tucker, 1986). In a set of recommendations for a "Liberal Arts degree in Computer Science", Gibbs and Tucker gave the following definition of the field's domain and its emphases:

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[18] See Appendix A for a set of bibliographic references with discussions about the discipline of computing and its branches across its history. Appendix B groups recent discussions about Software Engineering. Appendix C lists similar references in Human-Computer Interaction.

1986 Norman E. Gibbs and Allen B. Tucker

A Model Curriculum for a Liberal Arts Degree in Computer Science (Gibbs and Tucker, 1986, p 204). (see Figure 1.6).

Computer Science is the systematic study of algorithms and data structures, specifically

(1) their formal properties

(2) their mechanical and linguistic realizations

(3) their applications

[...] It is important to reaffirm the essential ordering of emphasis among these three components listed above. The *formal properties* (1) of algorithms and data structures must be overemphasized over their specific machines and languages (2), as well as their applications (3), in order for a program to be legitimately called *computer science*. If (2) takes precedence over (1), then the program might be called *computer engineering*; if (3) takes precedence, the program might be called *information systems*. (Neither of these alternatives is considered in this report).

Gibbs and Tucker's definition is interesting for the study of disciplinary relations because it approaches the field's subject matter not as a single domain, sharply delimited, but as a constellation of interests. This definition implied that the boundaries among Informatics disciplines could be not sharply delimited. In Figure 1.6, I represent Gibbs and Tucker model as graphic weighted averages: as constellations of interests. In 1989, the following definition of computer science and engineering was given in what became known as the Denning report:

1989 Peter J. Denning and Douglas E. Comer and David Gries and Michael C. Mulder and Allen Tucker and A. Joe Turner and Paul R. Young

Computing as a Discipline (Denning et al., 1989, p 16)

Computer science and engineering is the systematic study of algorithmic processes – their theory, analysis, design, efficiency, implementation, and application – that describe and transform information. The fundamental question underlying all of computing is, "What can be (efficiently) automated?"

As in the Denning report, the excessive emphasis on programming was also criticized in the next set of recommendations, Curricula 91. The 1991 committee wrote

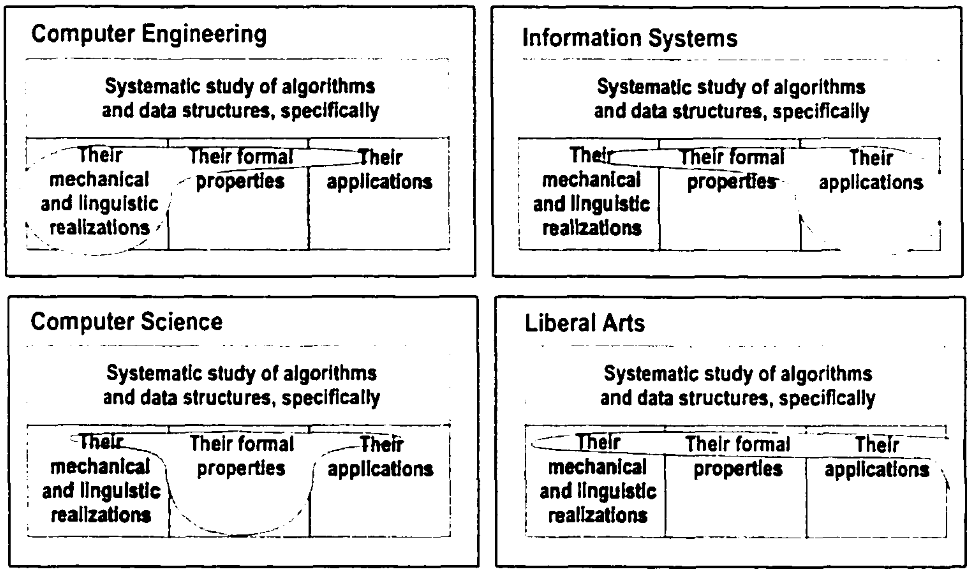

Figure 1.6: **Informatics different constellations of interests:** Illustration based on quoted text (Gibbs and Tucker, 1986, page 204).

that the emphases given to different topics did not permit a balance between experimental and theoretical computer science. A focus on algorithms rather than on programming was an attempt to rescue some of the field's initial orientation. This is clearly stated in Curricula 91:

1991 *Computing Curricula 1991:* ACM/IEEE-CS Joint Curriculum Task Force (Denning et al., 1989, p 9)

The view that "computer science equals programming" is especially strong in most of our current curricula: the introductory course is programming, the technology is in our core courses, and the science is in our electives. This view blocks progress in reorganizing the curriculum and turns away the best students, who want a greater challenge. It denies a coherent approach to making experimental and theoretical computer science integral and harmonious parts of a curriculum. The emphasis on programming arises from our long-standing belief that programming languages are excellent vehicles for gaining access to the rest of the field, a belief that limits our ability to speak about the discipline in terms that reveal its full breadth and richness.

In Curricula 91, the committee also stressed the "basic cultural, social, legal, and ethical issues inherent in the discipline of computing". As I mentioned, despite a respective course on Curriculum'78, it had not been enacted by most programs. As in Curriculum'78, the 91 commitee did not include such an area in the core courses of computing. However it stressed the importance of the area:

> 1991 *Computing Curricula 1991:* ACM/IEEE-CS Joint Curriculum Task Force (ACM/IEEE-CS, 1991, p 73)
>
> Undergraduates also need to understand the basic cultural, social, legal, and ethical issues inherent in the discipline of computing. They should understand where the discipline has been, where it is, and where it is heading. They should also understand their individual roles in this process, as well as appreciate the philosophical questions, technical problems, and aesthetic values that play an important part in the development of the discipline.
>
> Students also need to develop the ability to ask serious questions about the social impact of computing and to evaluate proposed answers to those questions. Future practitioners must be able to anticipate the impact of introducing a given product into a given environment. Will that product enhance or degrade the quality of life? What will the impact be upon individuals, groups, and institutions?
>
> Finally, students need to be aware of the basic legal rights of software and hardware vendors and users, and they also need to appreciate the ethical values that are the basis for those rights. Future practitioners must understand the responsibility that they will bear, and the possible consequences of failure. They must understand their own limitations as well as the limitations of their tools. [...]
>
> All practitioners must make a long-term commitment to remaining current in their chosen specialties and in the discipline of computing as a whole.
>
> To provide this level of awareness, undergraduate programs should devote explicit curricular time to the study of social and professional issues.

The absence of social and ethical issues in Curricula 91 core courses did not pass by without notice.[19] The proposed complementation of Curricula 91,which included social and ethical issues as fundamental, became known as the tenth strand. Many

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[19] See Huff and Martin (1995), Martin et al. (1996), and Martin and Weltz (1998)

other criticisms have been raised throughout the 1990s. For example, James E. Pitkow asked James Foley "what have been the primary characteristics of successful HCI students?" Foley answered:

1996 James Foley

The Evolution of the Student Experience: Interviews with Stuart Card and James Foley(Pitkow, 1996, page 29)

Pitkow: What have been the primary characteristics of successful HCI students?

Foley: An ability to get outside of themselves, to look at a problem as someone else might, to put oneself in another's shoes. This is the heart of understanding [User Interface] design. We design not for ourselves, but for our users. Coming at HCI [Human-Computer Interaction] from the computer science side, I find the biggest roadblock to be what I call "the arrogance of the technologist" who understands computers and can't accept that others might not understand them.

Although a focus excessively restricted on the product (hardware, software, or systems) has been tightly entwined in the professional identity and in the professional's attitudes, this problem has been recognized within the profession, both within academia and industry. For example, there is also agreement that graduates are not receiving the education that industries want, that they do not now how to communicate, and that they do not know how to work in teams (Lethbridge, 2000); that professionals and organizations are not capable of addressing mainstream customers (Moore, 1991); that they make use of euphemisms in relation to users (Cooper, 1999); that they need a "less parochial attitude" towards other sciences (Denning, 1984, page 982), and many others.

Although computer engineers, computer scientists, and information systems technologists shared interests, the daily practice of neither had fostered much interaction among them beyond their established roles and enacted disciplinary interfaces. David Lorge Parnas, who also advocates that software engineering is not computer science Parnas (1998, 1999), has recognized that computer scientists did not care about engineering (Parnas, 1990, p 18), and that engineers did not care much for software (Parnas, 1997):

1990 David Lorge Parnas

Education for Computing Professionals(Parnas, 1990, p 18)

In the early sixties, those of us who were interested in computing began to press for the establishment of computing science departments. Much to my surprise, there was strong opposition, based in part on the argument that graduates of a program specializing in such a new (and, consequently, shallow) field would not learn the fundamental mathematical and electrical engineering principles that should form its basis [...]

Nearly 25 years later, I have reluctantly concluded that our opponents were right.

1997 David Lorge Parnas

Software Engineering: An unconsummated marriage (Parnas, 1997, p 128)

When NATO organized two famous conferences on software engineering three decades ago [1968/69], most engineers ignored them. Electrical engineers, interested in building computers, regarded programming as something to be done by others – either scientists who wanted the numerical results or mathematicians interested in numerical methods. Engineers view programming as a trivial task, akin to using a calculator. To this day, many refer to programming as a "skill," and deny that engineering principles must be applied when building software.

Software engineering's domain has been characterized as being between computer engineering and computer science[20]. Some authors state that software engineering is included in the former, others state that software engineering is included in computer science, even others, that it is included in neither.

Mary Shaw characterized Software Engineering as a craft on its path toward professionalism through the cumulative inclusion of industrial, commercial, and scientific elements.[21] See Table 1.3. Therefore, for Shaw, software engineering depends on both.

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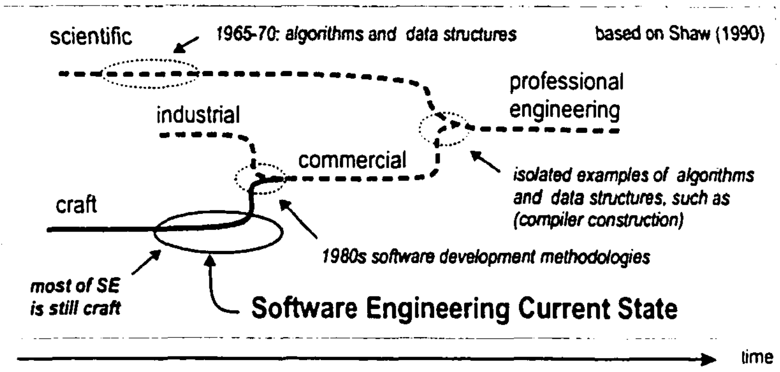
[20] See Appendix B for a long list of examples, including the Software Engineering Body of Knowledge (Bourque et al., 1998, p 11), and a series of article with suggestive titles: "Software Engineering: and unconsummated marriage" (Parnas, 1997), "Computer Science and Software Engineering Filing for Divorce" (Denning, 1998), "Stop That Divorce!" El-Kadi (1999), and "Software Engineering Programs Are Not Computer Science Programs" (Parnas, 1999)

[21] Coplien (2000) argued that to be human oriented, software design needs to shift its focus from objects and tools to people, and this implies a return to craftsmanship.

Mary Shaw described the evolution of the engineering disciplines as a progressive evolution from craft to professional engineering through a merge of economic and scientific interests and associated required transformations (Shaw, 1990, p 17).

In the evolution of civil engineering, for example, Romans merged the craft of dwelling construction with production practices to build urban and transportation infrastructure. Centuries later, advancements in the science of statics and of strength of materials, together with commercial interests gave rise to professional civil engineering around the nineteenth century.

For Shaw, chemical engineering is a younger discipline. Its commercial applications arose only at the end of the eighteenth century, with the development of an industrial alkali process. Later on, the development of atomic theory, joined with what was learned from the industrial production and commercial interest, bootstrapped the development of unit operations around the turn of the twentieth century.



According to Mary Shaw, Software Engineering is still in its craft stage of evolution. There are some isolated examples that can be characterized as scientific, commercial, and professional contributions such as algorithms, software development methodologies, and compiler construction, respectively. See Shaw (1990, page 17) and Gibbs (1994, page 92).

Organizational and commercial issues have been included across engineering programs throughout the early nineteenth century. David F. Noble (1977, 1984) has critically analyzed how industrial and commercial interests have dictated engineering curricula in the United States.

Table 1.3: **Software engineering development**

The emergence of Computing Science passed through a similar kind of argumentation (Newell et al., 1967) (Wegner, 1970).

It is interesting to note that the emergence of fields such as Software Engineering and Human-Computer Interaction happened during a period in which some specializations in Informatics were acquiring recognition and stability by narrowing their breadth and increasing their depth. Although, software engineering is often characterized as between computer engineering and computer science, a close analysis of its proposed body of knowledge unveils a set of topics related to people and organizations such as cognitive science, project management, and management. These topics have been part of Information Systems and Information Systems Management (See Ashenhurst (1972), Nunamaker Jr. et al. (1982), and Gorgone et al. (1999)). The domain of what is called empirical experimental software engineering also extends the focus of software design towards requirements and testing (Basili, 1992).

The emergence of new areas of study, professional occupations, quarrels on established boundaries, inter-disciplinary work, all indicate that Informatics' traditional disciplinary organization is becoming inadequate. There is no recipe to reorganize informatics, but individuals and committees have already expressed their opinions on how to renew and reorganize the field.

1.7 Renewal and Reorganization

In 2000 an IEEE-CS ACM joint task force recognized the "expanding" scope of the profession. As I write this thesis, Curricula 2001 is in preparation. The respective committee has already expressed the view that the sustained narrowing tendencies of prior similar recommendations are currently inadequate. Indeed the task force began its work with a restricted scope on computer science and engineering, as in the Curricula 91. Later on, it reviewed its initial decision giving the following reasons to enlarge the scope of the recommendations:

2001 The Joint Task Force on Computing Curricula IEEE Computer Society and ACM
Computing Curricula 2001, (IEEE-CS/ACM, 2001a, p 2)

(a) Narrowing the discipline of computing to its traditional components limits the evolution of the discipline through synergies with related fields.

(b) Introductory courses that are designed only for potential computer science majors will not serve the best interests of computing education as a whole.

(c) Taking a broader view of the computing field may make it possible for institutions to share resources.

(d) The other disciplines that comprise the broad field of computing are at least as important to the academic computing curriculum as traditional computer science.

As direct criticism of past reports, the committee explicitly stated the limitation of traditional approaches based exclusively in science and engineering. The 2001 committee continued:

2001 The Joint Task Force on Computing Curricula IEEE Computer Society and ACM
Computing Curricula 2001 - Volume II, (IEEE-CS/ACM, 2001b, p 2)

Computing has changed dramatically over that time in ways that have a profound effect on curriculum design and pedagogy. Moreover, the scope of what we call computing has broadened to the point that it is difficult to define it as a single discipline. Past curriculum reports have all too often regarded computing as synonymous with computer science or computer engineering. While such an approach may have seemed reasonable thirty years ago, there is absolutely no question that computing in the 21st century encompasses many vital disciplines beyond these two.

Jaan Valsiner developed a representation of personal developmental trajectories as dynamic systems (Valsiner and Lawrence, 1996, page 89). Using the same approach, I depict the traditional branches of Informatics and some emergent ones in Figure 1.7. I should remark that the scope of each specialization denotes their common discussed intersection. In the diagram the domain of Human-Computer Interface is a projection of Human-Computer Interaction. I place Software Engineering between Engineering and Science, although I am aware that it has a strong organizational perspective. I depict Information Science as apart from the others, and as having a bifurcation

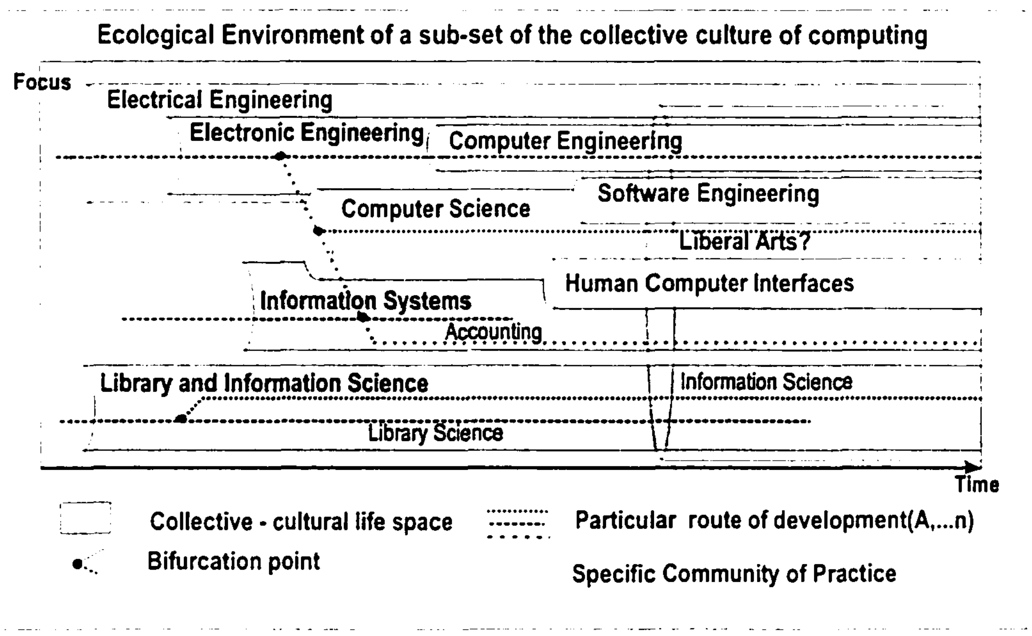


Figure 1.7: **Trajectories of Informatics' development**

point in which Information Science has separated from Library Science.[22] I place Liberal Arts Informatics as abridging the whole field of Informatics.

In Figure 1.7 the scope of each branch is depicted as constant across history. But an historical representation of scope demands a higher level of detail. The actual variations in scope are key to a reflection on the isolationist tendencies or on the emergence of new fields of Informatics, as discussed until here.

In Figure 1.8, disciplinary breadth variations are depicted in relation to the traditional branches of informatics. The narrowing and expanding tendencies are delimited by two lines. The approximate scope of several documents have been abstracted to depict the overall dynamics. The ellipses in Figure 1.8 depict the approximate perspectives adopted by professionals and committees. Some professionals, such as David Parnas, tend to reinforce boundaries, others, such as Peter Denning and Wolfgang Coy, tend to blur them. The bolder lines depict the approximate Computing Sci-

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[22] See Vakkari (1991) for a discussion on the relation between Information Science and Library Science. He understands that the former includes the latter because it is not restricted to a specific kind of organization.

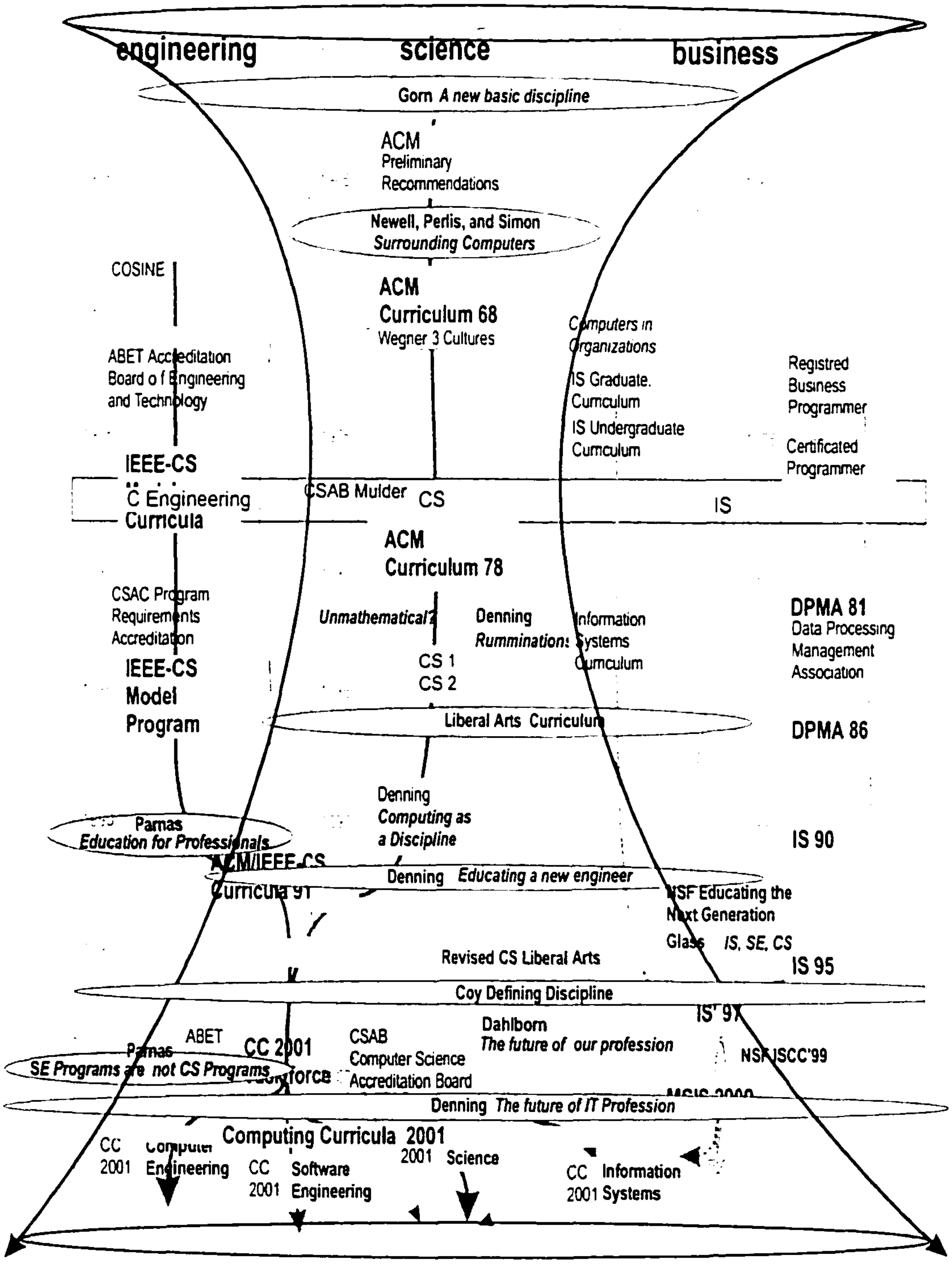
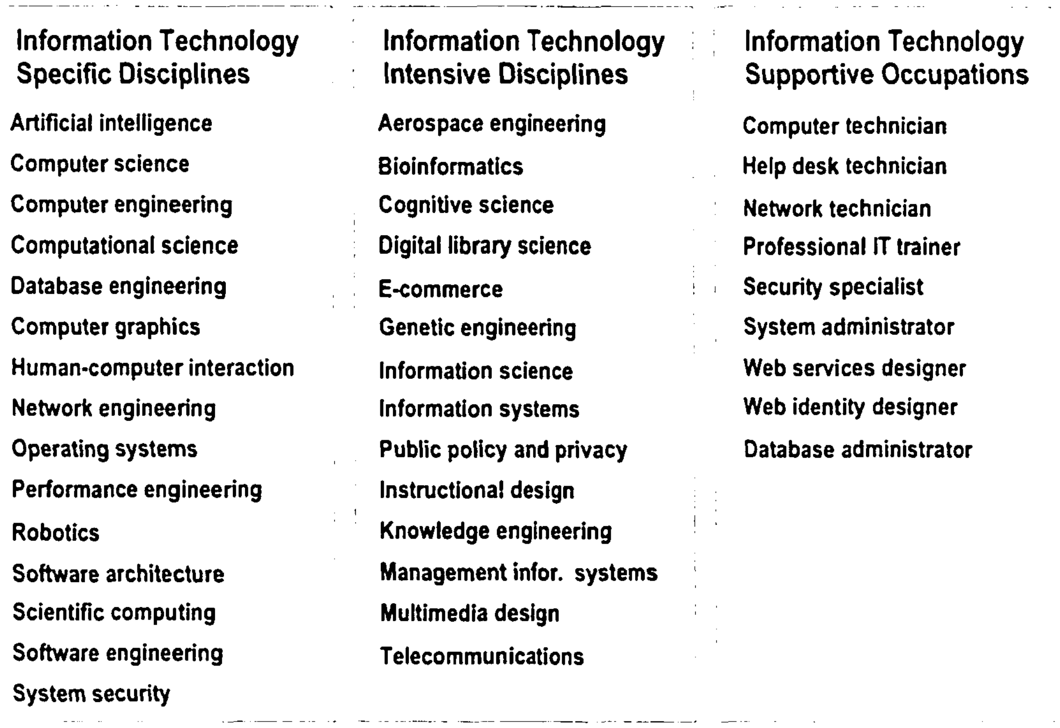


Figure 1.8: **Scope of Computing Science's nebulae of interests across its development:** The scope variations of the computing science field, for example, can be explored according to the individual opinions about the profession throughout its development.

ence domain projected on the technical dimension. The lighter lines depict computer engineering and information systems boundaries. I have represented a smaller gap between computer engineering and computer science than between computer science and information systems.[23]

Figure 1.8 depicts only a small subset of the actual disciplinary diversity present in Informatics. It is limited to three branches and their relations are reduced to linear scale. As mentioned on Table 1.1, the number of disciplines that have a role has expanded in the last few years. Denning listed thirty eight areas directly related to Information Technology (Denning, 2001). He grouped them as IT specific disciplines, IT intensive disciplines, and IT supportive occupations. See Figure 1.9. Denning's list illustrates both the current diversification found in the field, and the recent increase in breadth and heterogeneity of Information Technology related professions.



Information Technology Specific Disciplines

Artificial intelligence
Computer science
Computer engineering
Computational science
Database engineering
Computer graphics
Human-computer interaction
Network engineering
Operating systems
Performance engineering
Robotics
Software architecture
Scientific computing
Software engineering
System security

Information Technology Intensive Disciplines

Aerospace engineering
Bioinformatics
Cognitive science
Digital library science
E-commerce
Genetic engineering
Information science
Information systems
Public policy and privacy
Instructional design
Knowledge engineering
Management infor. systems
Multimedia design
Telecommunications

Information Technology Supportive Occupations

Computer technician
Help desk technician
Network technician
Professional IT trainer
Security specialist
System administrator
Web services designer
Web identity designer
Database administrator

Figure 1.9: **Denning's list of IT disciplinary diversity**

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[23] It is possible to correlate these gaps with the distinction between the traditional concepts of hardware and software, and between design and deployment.

Disciplinary diversity and heterogeneity is a challenge. Only some disciplines mentioned by Denning (Figure 1.9) have been recognized as part of the profession. Other ones have been considered areas or topics within a specific branch. Still others have been excluded from its domains or have never been included. For example, library science, graphic design, and instructional design may have had and may have a strong influence on the development of Informatics. The area of Linguistics, for example had a strong influence on theory of computing. Today, it has been incorporated within theory of computing, and most people interested in linguistic issues describe their area within artificial intelligence. However, the above areas have strong links with departments and practices associated with the human and social sciences, or the arts and humanities. How they can contribute or have contributed to informatics is a question that has no definitive answer. Indeed, the question of how to accommodate and negotiate disciplinary niches and interfaces will always be an open one. My objective in these two initial chapters is restricted to systematically mapping these disciplinary relations in order to facilitate the comprehension of their dynamics. For people in Informatics, one of the challenges ahead is to overcome the orthodoxy consolidated in professional practices. This will demand a deeper study than the one initiated here.

Besides Software Engineering and Human-Computer Interaction, there are several other areas emerging in Informatics. The challenges are amplified by the contempt in which some professionals hold foreign areas. I have mentioned only some of them in the preface. Two other examples are Software Design, and Organizational or Social Informatics. Löwgreen and Stolterman, for example, mentioned the discipline of design as a possible resource to ground the design of software:[21]

> 1999 Jonas Löwgreen and Erik Stolterman
>
> *Design Methodology and Design Practice* (Löwgren and Stolterman, 1999, p 13)
>
> There are good reasons for considering the development of software design as a discipline.

---

[21] See also Winograd (1995); Winograd et al. (1996) and Denning and Metcalfe (1997) for a deeper discussion on software design and related issues.

[. . .] Design methodology as a general field has developed across disciplines, primarily architecture, engineering design, and industrial design. This body of knowledge is not well known in our discipline but appears to be highly relevant.

The definition of Organizational Informatics, for example, stresses the effects of technology on people, organizations, and society. More recently, Kling used the term Social Informatics:

1993 Rob Kling

Organizational Analysis in Computer Science (Kling, 1993, p 75)

Organizational Informatics denotes a field that studies the development and use of computerized information systems and communication systems in organizations. It includes studies of their conception, design, effective implementation within organizations, maintenance, use, organizational value, conditions that foster risks of failure, and effects for people and an organization's clients.

1999 Rob Kling

What is Social Informatics and Why Does it Matter? Kling (1999)

A serviceable working conception of "social Informatics" is that it identifies a body of research that examines the social aspects of computerization. A more formal definition is "the interdisciplinary study of the design, uses and consequences of information technologies that takes into account their interaction with institutional and cultural contexts."

Human-centered approaches in Informatics are as old as Informatics itself. With the restriction of its foci on artifacts[25] these approaches remained on the outskirts of the profession for a while. Their resurgence started in the 1980s. I analyse the field of Human-Computer Interaction in the next chapter. In the sequel, I present a reorganization of Denning's list with the use of two layers (see Figure 1.10), and two scales. One layer is centered on the human and the other on the artificial aspects of Informatics. One scale is the technical scale discussed until now. The other organizes

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[25] I see several drawbacks in characterizing human-centered approaches in contraposition to machine-centered ones. I am proposing a disciplinary model that has multiple dimensions because I understand that human and machine perspectives complement each other.

Informatics disciplines according to the main activities that are ascribed to each discipline in terms of process.

Figure 1.10: **Disciplinary diversity organization: draft of a layered model**

The technical layer is represented in the upper half of Figure 1.11. It concentrates the specializations which have an identity and a subject matter traditionally focused on the technological aspects of IT. The human layer, represented in lower half of Figure 1.11, groups those specializations whose identity and subject matter have been traditionally constrained to a focus on the human elements of IT. The ordinate (vertical dimension) of both layers represent the scale of the subject matter of the specializations.

The disciplines or occupations are plotted according to their foci. Their boundaries usually cut across different scales and layers. In each layer, the abscissa (horizontal scale) represents the main activity of each specialization considering the life-span of a product. Time is not represented in this diagram, therefore, a longer life-span does not imply that such s discipline or occupation comes after another one with a shorter life-span.[26] The ordinate is organized according to the technical dimension or scale used until now. When two or more specialization are in different layers, or even when one specialization spans through more than one layer, the discrete nature of the representation helps to reinforce their differences, instead of their similarities. For example, it fosters views that Human-Computer Interfaces and Human-Computer Interaction are different fields, instead of fostering views that say that the two have different emphases and are dependent on each other.

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[26] See Chapter 3 for a discussion on technological and organizational lifecycles and how they are related to the historical development of Informatics.

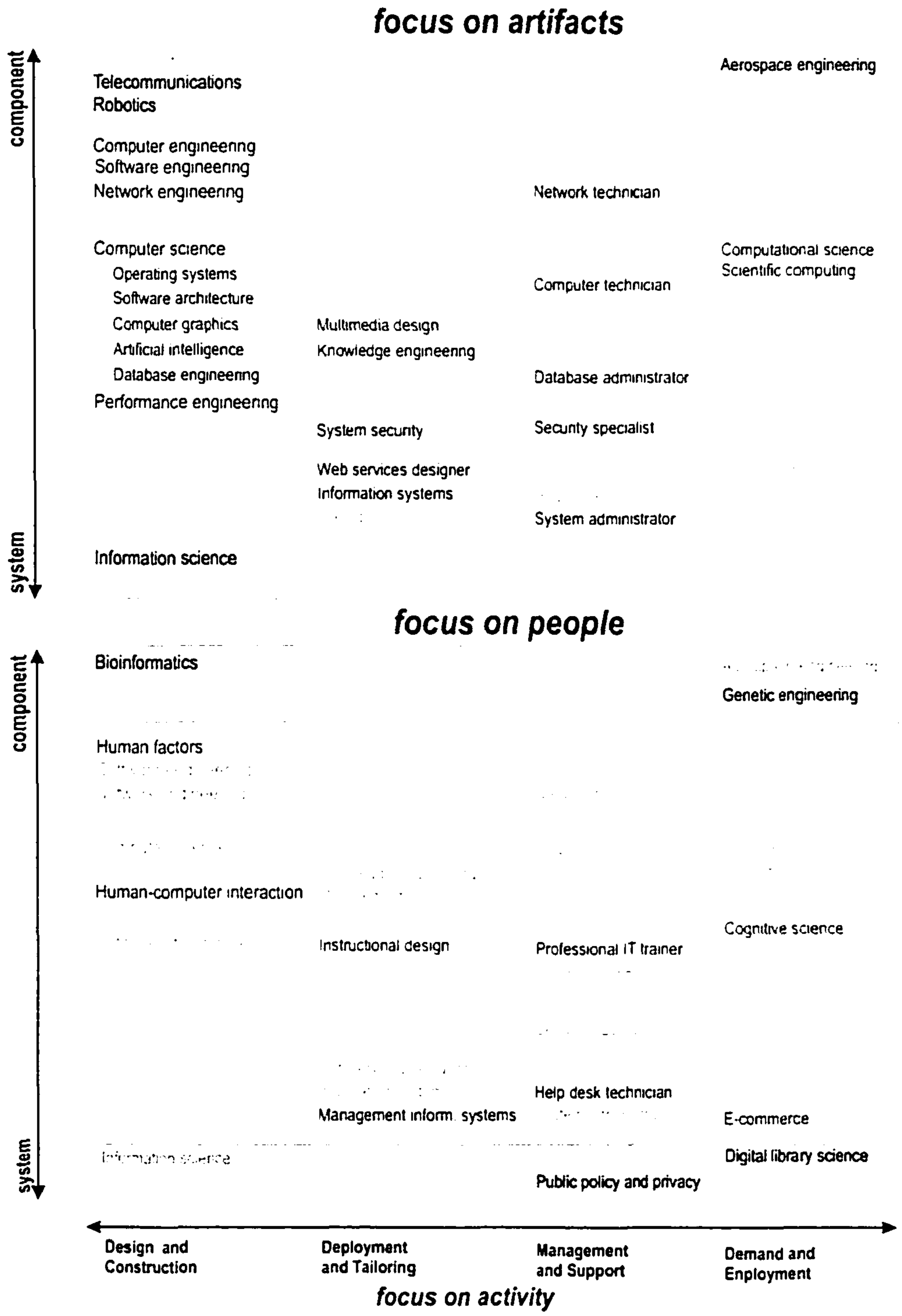

Figure 1.11: **Denning's IT list organized in a two layered model:** The specializations represented in lighter gray are from the other layer and are intended to give a sense of relative position.

1.8 Summary and Final Remarks 1

The academic communities directly associated with informatics have varied their scope in order to grow across a significant part of their development. This chapter explores the historical development of informatics using the trajectory of major professional associations, curricula recommendations, and the related literature. It illustrates how it is that such an innovative field turned into a conservative one.

Informatics' consolidation or growth is usually associated with the great depth that its communities have developed within certain subjects. Throughout this historical process of consolidation, the involved communities raised many barriers and bridges that end up structuring the field of Information Technology, as well as the field of Human-Computer Interaction (HCI). By narrowing the kind of phenomena disciplines such as computer engineering, computing science, and information systems comprised, these communities have been able to consolidate themselves as established fields of knowledge. Interests in cybernetics, systemic approaches, linguistics, and anthropology have been slowly left out of the core issues of the profession. Computer Engineering, Computing Science and Information Systems developed narrow but complementary constellations of interests focused on hardware, software, and systems, respectively. This decrease in diversity and increase in focus may have been appropriate in the past, but it should be revised in the future. Awareness of this dynamics can help the reorganization of informatics as a whole, including a better understanding and appraisal of the roles that some recently emerged fields can play.

One of the issues that I addressed in this chapter is intended to shed some light on how an often vibrant field such as Informatics eventually produces narrow-minded professionals. The expanding nature of informatics and its successes are not enough to justify the over-specialization of its professionals. Indeed, Informatics has reached a point at which a non-reflective practice[27] may hinder its development.

The development of a field, a profession, a discipline, a research topic happens

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[27] (Shön, 1983; Shön and Bennett, 1996) explores design as reflective practice, as a conversation with materials.

not only at its center or focus, but also on its boundaries and beyond them. Current research trends and professional criticisms can be characterized as having or demanding foci that go beyond Informatics' recognized technical dimensions. For example, a product centered design can be enriched with perspectives that stress not only the connectedness between product and process, between management and project size, between interests and consequences among development, use, evaluation, and disposal, but also the consequences of remembering and forgetting, seeking and discarding, teaching and learning, developing and using. It interweaves the imaginary with the concrete, making possible for designers to make their dreams become reality via a negotiation with materials.

Considering the period after the 1980s, the profession of informatics has been increasingly concerned with human issues by the direct inclusion of individual and collective issues in fields such as Human-Computer Interaction and Computer Supported Cooperative Work, or by indirect reference to managerial and economic issues in fields such as Software Engineering and Electronic Commerce.

Although Informatics promises easy to learn and use technology, phenomena associated with cognition and communication have not been the foci in which mainstream Informatics has developed greater depth. The recent increase of Informatics' footprint demands the exploration of new realms, what can be facilitated through cross-pollination with disciplines that have been studying these realms for some time. Indeed, several new professions and occupations related to informatics have emerged, bringing heterogeneity to it, and forcing a disciplinary reorganization.

As I have said, some of these endeavors have been forgotten in the past. But, absorbed, transformed, or discarded, they have continued to play a role in subsequent stages of professional development. Currently, fields such as bio-computation, computer algebra, medical informatics, software ergonomics, software engineering, human-computer interaction, computer-supported cooperative work, computer semiotics, computer mediated education, information management and retrieval, social informatics, computers and law, electronic commerce, and web-services design have their strength exactly grounded on the cross-pollination from two or more apparently autonomous traditional disciplines.

From a Peircean perspective, the theoretical understanding of computing is still an isolated phenomenon, restricted to the realm of an isolated machine. Exceptions point to interactive machines, and towards a shift from product driven design processes to human driven ones, what adds a second facet to Informatics, and leads to the second chapter.

The main contribution of this chapter is the introduction of a multidimensional model that enables the graphic representation of disciplinary constellations of interests. In this chapter only the technological dimension is explored in respect to how it has developed. Each dimension and corresponding scale can be used to differentiate different perspectives or interests.

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Chapter 2

Human-Computer Interaction

Amid the good things of this here-and-now world are also to be found false connections that distort the authentic nature of things, false associations established and reinforced by tradition and sanctioned by religious and official ideology. [. . .]

It is necessary to destroy and rebuild the entire false picture of the world, to sunder the false hierarchical links between objects and ideas, to abolish the divisive ideational strata. It is necessary to liberate all these objects and permit them to enter into the free unions that are organic to them, no matter how monstrous these unions might seem from the point of view of ordinary, traditional associations. These objects must be permitted to touch each other in all their living corporeality, and in the manifold diversity of values that they bear. It is necessary to devise new matrices between objects and ideas that will answer to their real nature, to once again line up and join together those things that have been falsely disunified and distanced from one another – as well as to disunite those things that had been falsely brought into proximity. On the basis of this new matrix of objects, a new picture of the world necessarily opens up – a world permeated with an internal and authentic necessity.

Thus, in Rabelais the destruction of the old picture of the world and the positive construction of a new picture is indissolubly interwoven with each other.

Mikhail M. Bakhtin (Bakhtin, 1981, p 169)

2.1 Introduction to the Cultural Ecology of HCI

In Chapter 1 I have explored the historical academic roots of Informatics with a focus on computer science education. I have introduced a technical dimension and I have indicated the possibility of using other dimensions to describe Informatics' disciplinary composition.

In this chapter I explore the nature of HCI through its historical and cultural academic roots and propose a model based on human/technical/interactive dimensions to characterize HCI's disciplinary cultural ecology across history.

The level of abstraction of this model is in consonance with the topics that the ACM committee included in the SIGCHI Curricula for Human-Computer Interaction under the nature of HCI (Hewett et al., 1992). It is a theoretical framework that enables an overview of phenomena involved in the communication among and across people and information artifacts (e.g. computers). The respective SIGCHI committee listed four topics as part of the nature of HCI:

1992 *ACM SIGCHI Curricula for Human Computer Interaction* Hewett et al. (1992)

- **Points of view**: HCI as communication, agent paradigm, tool paradigm, the work centered point of view, human/system/tasks division, supervisory control
- **Objectives** (e.g. Productivity, user empowerment)
- **History and intellectual roots**
- **HCI as an academic topic**: journals literature, relation to other fields, science vs. engineering vs. design aspects

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Ecological approaches in Informatics and in HCI have not been much explored. Indeed, the number of works that make references to ecology or ecological metaphors in HCI and Informatics is small and scattered. I should remark that the meaning I am ascribing to the term ecology here is broader, but shallower, than domains restricted to phenomena related to natural resources. In this sense, it is closer to the origin of the word, which encompasses "the study of the house", and to the original meaning of ecology, which included phenomena today labeled as human and or cultural ecology. Table 2.1 groups some uses of the term ecology across Informatics.

Ecological metaphors have been used by some authors who used a systemic perspective to structure Informatics and its role in society. For example, Siefkles discussed computer science through an ecological approach (Siefkles, 1995). With a focus on interface development, Rasmussen called his approach *ecological interface design* (Rasmussen and Vicente, 1989; Vicente and Rasmussen, 1992; Christoffersen et al., 1998). In information systems, *Information ecology* appeared in Hasenyager (1996), who explored activities of maintenance and development in the management of information technology, and in Davenport (1997) who employed the term very loosely.

Nardi and O'Day used *information ecologies* metaphorically as a *system of people, practices, values, and technologies in a particular local environment* (Nardi and O'Day, 1999, p 50). By focusing not on technology, but on people's activities, Nardi and O'Day proposed a middle point between uncritical acceptance and blanket rejection of technology, discussing a wide range of cases, from libraries and schools to the internet.

Susan Leigh Star has been using the term extensively. She has deeply explored a mechanism labeled *boundary objects* in which *institutional ecologies* sustain their relationships and their integrity, even in the presence of diversity (Star and Griesemer, 1989; Star, 1995).

In 1969, Postman referred to the tendency towards stability in physiological systems (homeostasis) to approach educational activities in the light of cybernetics (Postman, 1969, 1979), and used the term *media ecology*. In mass media, Fosberg also used media ecology, but to analyze television (Forsberg, 1993). Blondheim explored mass multimedia networks as information ecologies (Blondheim, 1994), and Altheide referred to the *ecology of communication*, or the *structure, organization, and accessibility of various forums, media and channels of information* (Altheide, 1995, p xi).

Gregory Bateson's book "Steps to an Ecology of Mind" (Bateson, 1972) and James J. Gibson's book "The Ecological Approach to Visual Perception" became classics (Gibson, 1986). The concept of affordance used in HCI was introduced by Gibson. See also Tudge et al. (1997) for Environmental Psychology. The term cultural ecology has been used in Geography since the sixties, and it encompasses the study of the interactions between people and their environment. According to Butzer it is not well known even in Geography (Butzer, 1989, p 192). See also Hardesty (1981) and Turner II (1989). The term human ecology has a longer history, both in Geography (Barrows, 1923) and in Sociology (Eufrásio, 1999), in which it played an important role at the Chicago School of sociology in the first half of the century, and in other disciplines. See Kingsland (1991) for a general introduction to ecology; Evans (1956) for the concept of ecosystem; and Van Dyne (1969) applications in natural resource sciences.

Table 2.1: **References and uses of "Ecology" across Informatics and HCI**

HCI, media studies, and psychology, and some references to basic literature.

I initially address the current and the past disciplinary diversity present in HCI, different opinions about the directions of its development, and how it has been modeled in the literature. In the sequel, I propose a multidimensional conceptual model of HCI's disciplinary fabric, and illustrate its use in the visualization of HCI's historical foci according to different points of view found in the literature. I conclude with a discussion about the role of communicative phenomena in HCI and the disciplines, mostly housed in the Humanities, that study them. I indicate the existence of a gap between HCI's recognized theories and disciplines and its practices and cultural responsibilities.

The disciplinary trajectory of HCI has several points in common with the trajectory of Informatics described in Chapter 1.[1] In a snapshot, the HCI community was also uncomfortable with its disciplinary plurality present during its consolidation years. The field did not have an identity, was scattered, and was not recognized in academia. The HCI community narrowed its interests in order to build an aimed identity and academic recognition. Throughout the process, only a few branches had significant growth during its consolidation. For example, perspectives associated with traditional cognitive science (information processing models based on abstractions of autonomous computing machines) outgrew perspectives that were focused on social phenomena. Nevertheless, as phenomena related to Informatics grew undeniably beyond the individual user and individual machine other branches emerged, sometimes within, sometimes outside HCI's established domain and order. Broadly speaking, there is no accepted label that bridge the different groups or branches. For example, fields such as Computer Supported Cooperative Work (CSCW) developed a distinct identity outside traditional HCI.

A comparison of HCI' and Informatics' constellations of interests shows significant differences too. In this thesis I am construing the term HCI broadly, encompassing fields such as Human-Factors, Cognitive Engineering, Cognitive Ergonomics.

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[1] In Chapter 1, I have addressed the historical transformation of Informatics' disciplinary diversity, and the current challenges associated with its renewal and reorganization.

Computer Supported Cooperative Work, Groupware, Computer Semiotics, Computer Mediated Communication, and others. However, I envision HCI and Informatics as undeniably interwoven. Currently, they have a lot to learn from each other, and from other disciplines and areas left on their outskirts.

It is possible to say that HCI basically disappeared during the 1970s. Once HCI re-emerged as a field in the eighties, it never achieved the same degree of recognition or disciplinary segmentation as Informatics did during its development. As HCI matured as a field, the initial discomfort towards its multiple foundations was slowly recognized as one of its advantages. Likewise, the importance of diversity within HCI's disciplinary structure had been discussed earlier than in Informatics. It happened already in the late 1980s and early 1990s.

After presenting and discussing issues related to HCI's disciplinary diversity, I propose a multi-dimensional model for charting the disciplinary cultural ecology of Human-Computer Interaction. The introduction of a multi-dimensional model is intended to enable a synoptic disciplinary view of HCI's nature. This model is the main contribution presented in this chapter. In relation to subsequent chapters, such a model enables me to delimit the contribution of a theoretical study of communication in HCI, a perspective which has received limited recognition until now, and one that has not been much explored.

2.2 In the Search of Theoretical Foundations

While across Informatics there still is resistance towards difference, towards disciplines in the social sciences and humanities as sources of theoretical principles, but not as application areas, in HCI there is a certain agreement that its nature is interdisciplinary and should remain as such. Throughout the development of HCI, the community assumed different attitudes towards the field's foundations. Indeed, the pattern followed by informatics of reducing disciplinary breadth and increasing its depth in a first consolidation phase is also present in HCI.

During the sixties, for example, precursors of HCI, had highly interdisciplinary interests and explored a wide range of phenomena. The examples I give in the sequel discuss issues that today lay in the realm of HCI, but it is impossible to classify those early initiatives as being in Informatics, in computer science, in HCI, or whatever other field, simply because there were no such fields.[2]

An example in human-factors in electronics illustrates that concerns similar to HCI were already present in the early sixties. In the first of the only few issues of the IRE (Institute of Radio Engineers) journal entitled "IRE Transactions on Human Factors in Electronics" Curtis M. Jansky made an appeal to the engineering community for cooperation with the field of Human Factors. The journal was later discontinued with the merging of the AIEE and the IRE. Jansky wrote:

> 1960 Curtis M. Jansky
>
> *Guest Editorial, IRE Transactions on Human Factors in Electronics*
>
> (Jansky, 1960, p 3)
>
> As a start toward this sought-for definition, one may say that any field of Human Factors is concerned with the nature of communication of information between a human being and a machine, and is concerned with the engineering of man-machine systems. Since machines are designed to serve human beings, it would appear that Human Factors is every engineer's responsibility as it relates to the products they have under development[. . .]
>
> In general, it would seem that the reward of better designed products for our human society is available to the development engineer who uses Human Factors information throughout his development program, calling upon the services of specialists whenever refinements and extensions of the Human Factors art are required."

During the same period Douglas C. Engelbart, who developed the input device known as the "mouse", was also exploring different disciplines in the search for theoretical foundations. In 1962, Engelbart wrote a report in which he discussed the conceptual framework of a project aiming to augment the human intellect. The conceptual framework proposed by him consisted of Humans, Language, Artifacts, Methodology, and Training (H-LAM/T) and was grounded in many disciplines. A

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[2] See (Licklider, 1960) for a use of "man-computer symbiosis" during the 1960s, and (Lewis Jr., 1963) for discussing the relation between "men and machines" across the last few centuries.

quote from Engelbart's report illustrates the rich spectrum of disciplines present in his approach:

> 1962 Douglas C. Engelbart
>
> *Augmenting Human Intellect: A Conceptual Framework* (Engelbart, 1962)
>
> This report covers the first phase of a program aimed at developing means to augment the human intellect. These "means" can include many things–all of which appear to be but extensions of means developed and used in the past to help man apply his native sensory, mental, and motor capabilities – and we consider the whole system of a human and his augmentation means as a proper field of search for practical possibilities.[p 1] [. . .]
>
> This kind of system approach to human intellectual effectiveness does not find a ready-made conceptual framework such as exists for established disciplines. Before a research program can be designed to pursue such an approach intelligently, so that practical benefits might be derived within a reasonable time while also producing results of long range significance, a conceptual framework must be searched out – a framework that provides orientation as to the important factors of the system, the relationships among these factors, the types of change among the system factors that offer likely improvements in performance, and the sort of research goals and methodology that seem promising.[p 2] [. . .]
>
> An integrated set of tools and techniques will represent an art of doing augmentation research. Although no such art exists ready-made for our use, there are many applicable or adaptable tools and techniques to be borrowed from other disciplines. Psychology, computer programming and physical technology, display technology, artificial intelligence, industrial engineering (e.g., motion and time study), management science, systems analysis, and information retrieval are some of the more likely sources. These disciplines also offer initial subject matter for the research."[p 119]

Engelbart's research group at the Stanford Research Institute emerged in the sixties, became very strong in 1974, and collapsed in 1977. Engelbart was literally "swimming against the tide". Engelbart related that he, at the time, had not understood the dynamics that led to the group vanishing. Later on, he realized that it was "fairly clear to [him] that it isn't the market's fault if someone fails in trying to sell it something that it isn't ready for" (Engelbart et al., 1973; Engelbart, 1986).

Engelbart was attempting to enlarge the breadth of Informatics during a period in which there were strong narrowing forces focused on the artifact to be produced.

The history of the ACM Special Interest Group on Computer-Human Interaction (SIGCHI) gives another example of the narrowing tendencies in HCI. Formerly, SIGCHI was called the Special Interest Group on Social and Behavioral Computing (SIGSOC). Borman (1996) related that SIGSOC was having difficulties maintaining and attracting members during the seventies. It only grew, once it changed its denomination, becoming SIGCHI. According to her, due to the change, part of the former members interested in the social and behavioral aspects of technology or on applications of computing to related issues did not remain in the group.

Just a year after Engelbart's research group collapsed, but around two decades after his project with broad theoretical foundations, James D. Foley commented on the lack of theories about the use of computers. Foley gave a paper on "user-oriented interactive systems" in a "Conference on Easier and More Productive Use of Computer Systems", which was organized by SIGSOC. Foley wrote:

> 1979 James Foley
>
> *The development of user-oriented interactive systems* (Foley, 1979, p 9)
>
> To build effective user-oriented computer systems, we need to develop theories of how people use computer systems and process information. We also must construct models of various sorts. We need to apply those things that we know, and do a lot of teaching. Since we haven't been doing these things very effectively thus far, our computer systems are not particularly user-oriented or people-oriented.

I remark that the resurgence of Human-Computer Interaction in the late seventies partially coincides with the exclusion of similar issues within most branches of Informatics.

As I have already mentioned, although the ACM Curriculum'78 proposed a course on Computers and Society, the focus on software programming, narrowly understood, prevailed. I have not explored the issue, but there were probably very few people with interests and background in Computers and Society to teach such courses.[3]

I remark that I am not suggesting a causal link between the lack of development of Informatics and the development of HCI. What I am saying is that the direction of development of Informatics led people with interests in other directions to gather in different fields. The remark is important because the initial consolidation of HCI happened in resonance with Informatics and not in dissonance with it.

During the 1980s, HCI developed with one foot in cognitive psychology and another foot in computer science. Individual cognitive behavior was evaluated in terms of response times, keyboard typing speed, and memorization patterns. Methodologies focused on factors within a unity of analysis involving mostly one computer, one user, and short tasks such as the Goals, Operators, Methods and Selection rules (GOMS)(John, 1995), and User Interface Management Systems (UIMS) (Hartson and Hix, 1990). In terms of theory, the dominant view in HCI during the early nineteen eighties, was that information processing models and laboratory experiments were enough to guide the field's development. The information processing model, for example, assumed even to this day that a human cognitive system can be modelled as an abstract isolated computing machine that processes information. The feasibility of such a goal was soon criticized in the mid 1980s. Despite the criticisms, no alternative theoretical scaffold has been able to replace the established paradigm. The multiple alternatives and a consequent lack of direction left the community uncomfortable with the situation. After that, different perspectives have guided the field, proposing alternative and sometimes complementary sets of theoretical foundations.

Comments of researchers throughout HCI's history (see Table 2.2) illustrate different perspectives on the theoretical foundations sought for the field. After Engelbart's broad and plural conceptual foundations, the community attempted to hardened its foundations (Newell and Card, 1985), but it was soon criticized (Carrol and Campbell, 1986). The lack of results in establishing a single set of scientific foundations for HCI left the community with a feeling of confusion and lack of hope. For example,

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[3] Only an historical research will eventually clarify how much the restricted foci of the disciplines in Informatics helped the initial consolidation of HCI by clearly demarcating a boundary of interest.

1984 Donald A. Norman

Design Principles for Human-Computer Interfaces (Norman, 1984, p 1)

If we intend a science of human-computer interaction, it is essential that we have principles from which to derive the manner of the interaction between person and computer[...] Our design principles must be of sufficient generality that they will outlast the technological demands of the moment[...] This new field - Human Factors in Computing Systems - contains an unruly mixture of theoretical and practical problems.

1989 Marilyn Mantei

An HCI Continuing Education Curriculum (Mantei, 1989, pp 16-17)

Despite the intense interest in the field of Human-Computer Interaction [...], without a solid foundation summarizing the HCI body of knowledge, this field is in danger of disappearing[...] The question should be, not whether HCI has an adequate theoretical base, but how to elaborate and demonstrate this theoretical base. This is the role of the foundation builders.

1994 Gary W. Strong, J. B. Gasen, T. Hewett, D. Hix, J. Morris, M. J. Muller, D. G. Novick

New Directions in HCI (Strong et al., 1994, pp 24-26)

[F]undamental theory of HCI is scarce. As technology is relatively new, we have an exceptionally limited understanding of what people actually do, want to do, and could do with computing systems, much less with integrated computing and communication systems [...] A fundamental problem for interface developers and for the further development of the field itself is that we do not really know what it means to interact. This despite the fact that humans interact successfully with each other every day –and, rather less successfully with machines [...] [T]he lack of a basic theory directing the field may be a significant handicap to its continued progress.

1994 Yvonne Rogers, Liam Bannon and Graham Button

Rethinking Theoretical Frameworks for HCI (Rogers et al., 1994, p 28)

There was a general consensus, however, that the most 'scientific' use of a theory to propose and evaluate predictions about human performance was not appropriate for the current wave of theory building. The lesson learnt from attempts to apply information-processing models to human performance were taken as sufficient evidence that the field of HCI is too rich and complex to force into a set of hypotheses that can be quantitatively tested. Furthermore, the field is too diverse and changing to be formulated as a coherent theory of HCI.

Table 2.2: **HCI's theoretical foundations**: quotes

Norman described the field as not being successful in establishing one set of theoretical foundations, and as containing "an unruly mixture of theoretical and practical problems" (Norman, 1984, p 1). Mantei wrote that "without a solid foundation [... HCI was] in danger of disappearing"(Mantei, 1989, pp 16-17). The participants of a NSF committee recognized that "fundamental theory of HCI [was] scarce [... and could be ... a] significant handicap to its continued progress" (Strong et al., 1994, pp 24-26).

The process did not stop, and reached a disciplinary turning point. In the mid 1980s several authors such as Winograd and Flores (1990), and Suchman (1987) argued for the necessity of multiple perspectives in understanding phenomena involving people interacting with computers. Since then, a theoretical drift has gone from pursuing homogeneous foundations to weaving heterogeneous ones.[1] Rogers et al. summarized the consensus recently achieved as a healthy form of theoretical pluralism and characterized HCI as too rich and complex to be constrained by the previous tendencies (Rogers et al., 1994, p 29).

2.3 Disciplinary Diversity across HCI

Overall, HCI followed a similar pattern of that identified in Informatics. Its disciplinary diversity got reduced in the seventies, at the apex of the information processing model (which equates the human with the machine). HCI's decrease in diversity came after Informatics' decrease. As I mentioned before, human-computer issues were not seriously considered in Informatics' scope during its consolidation years. HCI became dormant in the seventies, and arose, dominated by a single approach, in the early eighties. The increase of diversity in HCI was discussed already in the mid eighties, and it grew at a faster pace than in Informatics, as I address in the following section.

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[1] See Card et al. (1983), Newell and Card (1985) and Moran (1985) for approaches that tended towards a narrow definition of HCI. See Carrol and Campbell (1986), Winograd and Flores (1990), and Suchman (1987) for works that intended to rescue HCI's breadth in the late 1980s.

In informatics, HCI really emerged in the mid 1990s, and it is being discussed now. Indeed, Human-Computer Interaction and other fields are enriching Informatics' foundations with human-centered perspectives.

Tables 2.3 and 2.4 list comments that describe the several perspectives on how the HCI community understood disciplinary diversity in the 1990s. In short, disciplinary diversity in HCI has been qualified as "highly controversial" (Preece and Keller, 1990, p 67), as tending to the centers of established fields, not the edges (Marchionini and Sibert, 1991, p 26), as "having a rich space of topics, some at the center, some at the periphery" (Hewett et al., 1992, p 7), as "in danger of being absorbed in a single discipline" (Hewett et al., 1992, p 79), as "being a loose umbrella or something new" (Bannon, 1992a), as being in the interest of many departments across universities (Strong et al., 1994, p 16), as "being under the risk of fractionalization" (Gasen, 1996, pp 25-26), and finally, as "having a healthy form of pluralism" (Rogers et al., 1994, p 29).

I should remark that Informatics, itself disciplinary-diverse, is only one of the fields on which Human-Computer Interaction relies and to which it contributes. Psychology, indeed, has dominated HCI. There are a whole set of disciplines/areas in the medical sciences, social sciences, and humanities that have been participating in the cultural ecology of phenomena involving people interacting with computers as well. Some of these disciplines are not considered as being within the realm of traditional HCI. Examples include: Medicine and physiotherapy in computer related health problems; anthropology in teamwork when mediated by technology; media, mass media studies and sociology in understanding internet communities and its social implications; economics and business in e-commerce; political science and law in technology privacy, accessibility, and crime related issues, among other. In other words, disciplinary renewal and a consequent reorganization is also pressing the HCI community to reflect on its foundations.

In the remainder of this chapter, I address the models that describe or model the nature of HCI, and propose an extension of these models in order to include the current disciplinary diversity present in the field.

1990 Jenny Preece and Laurie Keller

Key Issues in HCI Curriculum Design (Preece and Keller, 1990, p 67)

The multidisciplinary nature of HCI is identified as being highly controversial when deciding what to teach and how [...] Too often-stressed aspects about human-computer interaction (HCI) are its newness and its multi-disciplinary nature. These not only provide unique challenges to both researchers and teachers, they are also the source of problems.

1991 Gary Marchionini and John Sibert

An Agenda for Human Computer Interaction: Science and Engineering Serving Human Needs (Marchionini and Sibert, 1991, p 26)

HCI infrastructure development is complicated by the fact that the best research in HCI is highly interdisciplinary. It does not fall directly within the current disciplinary structure of Computer Science or Psychology, but right at the boundary between the two. Institutional pressures tend to lead researchers toward the centers of their disciplines, not the edges. For example, it is easier to achieve tenure in a department by doing work that is close to the center of its discipline.

1992 Thomas T. Hewett et al.

ACM SIGCHI Curricula for Human-Computer Interaction Hewett et al. (1992)

But it is clear that varying what is meant by *interaction, human*, and *machine* leads to a rich space of possible topics, some of which, while we might not wish to exclude them as part of human-computer interaction, we would nevertheless, wish to identify as peripheral to its focus. Other topics we would wish to identify as more central.[p 7][...]

One of the tasks left undone by this group is the specification of how HCI relates to various established disciplines. We currently feel strongly that HCI appears by nature to be multidisciplinary and would hope, as HCI develops further, that it does not get absorbed into a single discipline.[p 79]

1992 Liam Bannon

Interdisciplinarity and Interdisciplinary Theory in CSCW Bannon (1992a)

While that debate continues about the core issues in the emergent field of CSCW [Computer Supported Cooperative Work] [...], few would disagree with the observation that its interdisciplinary nature is a key feature. The attempt to meld viewpoints from such diverse fields as anthropology and software engineering has, however, created some difficulties and confusions[...] At issue is whether CSCW is simply a loose umbrella term which allows for people from a variety of different disciplinary perspectives to put forward their research traditions to a new audience, or whether there is something genuinely new and innovative being achieved through novel "interdisciplinary" research paradigms.

Table 2.3: **Comments on HCI's disciplinary diversity I**

1994 Jonathan Grudin

CSCW: History and Focus (Grudin, 1994a)

Some writers describe CSCW as an emerging field or discipline, but what we see today more resembles a forum, an undisciplined marketplace of ideas, observations, issues, and technologies. We expect to find shared or overlapping interests and we should also anticipate differences in interests and priorities. Everyone comes to a forum from someplace and returns there. In fact, people come from different places, and it is useful to know where each is from and why they have come. Each visitor can see what the others have to offer and can decide what is worth taking home. No one expects everything to be personally useful or all possibilities to be represented. There is no assumption that everyone speaks the same language, only that they will try to work out some means of communicating.

If we think of CSCW as an emerging field or common enterprise, we may be frustrated by this mosaic of different pieces, the frequent misunderstandings, and the lack of intellectual coherence. But when understood and respected, the differences form the core of richer, shared understandings.

1994 Gary T. Strong et al.

New Directions in Human-Computer Interaction (Strong et al., 1994, p 16)

[T]he material of HCI [...] can intersect with a wide variety of other departments, including engineering, psychology, communications, library and information sciences, business and even (especially in small colleges) humanities.

1994 Jean B. Gasen

HCI Education: Past, present, and future? (Gasen, 1996, pp 25-26)

The increasing specialization within the field, evident in more narrowly defined conferences and journals, is a double-edged sword. Such developments reflect the maturing and deepening of our body of knowledge. On the other hand, HCI runs the risk of fractionalizing both the body of knowledge and the HCI community as a whole by such specialized focus. Maintaining a broad, interdisciplinary view may become more difficult as the field advances.

1994 Yvonne Rogers, Liam Bannon, and Graham Button

Rethinking Theoretical Frameworks for HCI (Rogers et al., 1994, p 29)

It appears that theory building in HCI is becoming very much a growing cottage industry. The emergence of a polyphony of theories in HCI appears to be developing into a healthy form of pluralism. [...] theories are primarily working as heuristic tools [...] for systematically and constructively thinking about how to support and enhance working practices.

Table 2.4: **Comments on HCI's disciplinary diversity II**

I proceed with models that describe HCI's contents, as well as its disciplinary niches and their relationships across time. I start with conceptual charts of related disciplines.

2.4 Conceptual Charts and Disciplinary Scope

I am assuming that heterogeneity, rather than homogeneity, is the norm across HCI and Informatics understood broadly, not the exception. In this section I present a discussion of conceptual chaits based on examples found in information science, cognitive sciences, and language studies. These examples are intended to illustrate how some disciplines that are usually mentioned as part of HCI are themselves disciplinary diverse. I start with a common characterization of disciplinary diversity in HCI that uses balloons to represent this diversity.[5]

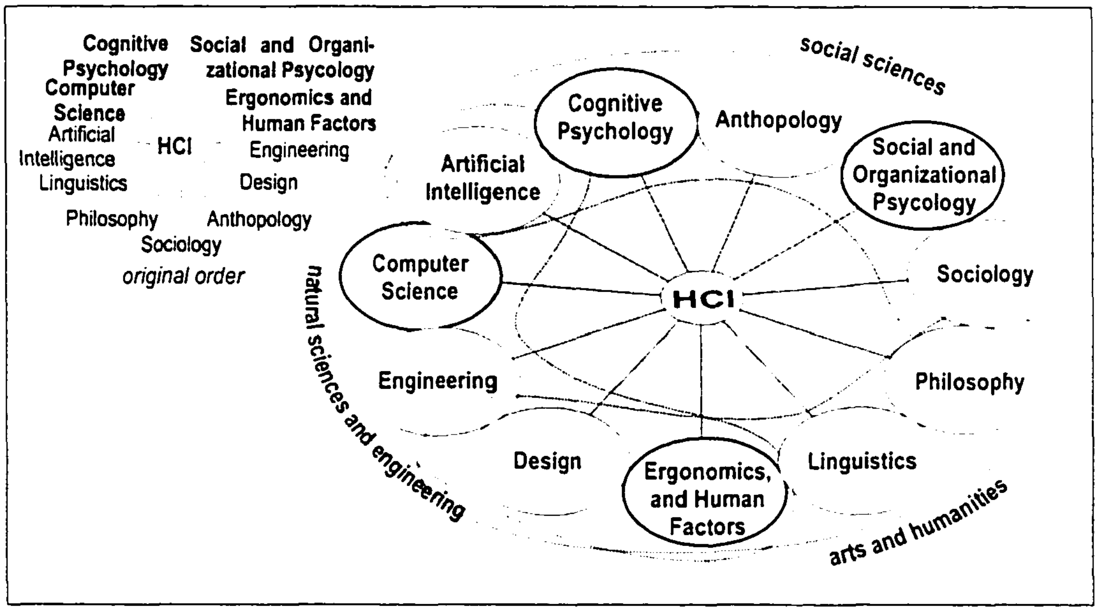

Figure 2.1: **Human-Computer Interaction's disciplinary composition.** See (Preece et al., 1994, p 38) for the original diagram sketched in the left upper corner.

Figure 2.1 depicts a balloon diagram based on an illustration of the disciplines

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[5] Sometimes balloons are used as Venn Diagrams as used in set theory to show the disciplinary intersections and interfaces.

related to HCI found in (Preece et al., 1994, p 38). I have reorganized the disciplines according to their current relation with the sciences and engineering, the social sciences, and the arts and humanities, adding a second level of abstraction to Preece et al.'s diagram.[6] Each of the disciplines included in Figure 2.1 also groups other disciplines and so own. In the sequel, I present some diagrams that chart the disciplinary diversity present in information science (Figure 2.2), cognitive science (Figure 2.3), and language studies (Figure 2.4).

In Chapter 1, I have included the area of Information Science as a discipline closely related to Informatics. Figure 1.6 depicted the constellation of interests of different emphases in Informatics in the context of liberal arts programs in computer science (Gibbs and Tucker, 1986, p 204) as a weighted foci, and was organized according to a technical scale. In Figure 2.2, I present a similar illustration based on a diagram and a description proposed by (Ingwersen, 1992) and cited in (Vakkari, 1994, p 11). Instead of a technical scale, Information Science's subject matter and the relation between its components organize this diagram around the relations between and within users (who desire and use information) and information systems (in and through which information is processed and represented). The areas of infometrics, information management, information (retrieval) systems, information retrieval interaction, and information need and use studies are differentiated according to their constellations of interests.[7] As mentioned earlier, Library and Information Science had a disciplinary bifurcation point on which library studies and information systems diverged from one another.

The several areas of Information Science illustrate the intricate dynamics involved

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[6] The use of balloons does not enable the direct representation of disciplinary transformations, a topic of interest in this dissertation. The regions and the interfaces described by the balloons are contingent on the historical period in which a disciplinary characterization is made. Different relations require different diagrams. The area of design, for example, is often characterized as science, often as art. During the nineteenth century, engineering was a useful art. Artificial intelligence has strong links with computer science, psychology, and linguistics. The diagram does not show the relationship, for example, between AI and linguistics.

[7] The delimited regions of Figure 2.2 follows Ingwersen (1992)'s description of Information Science.

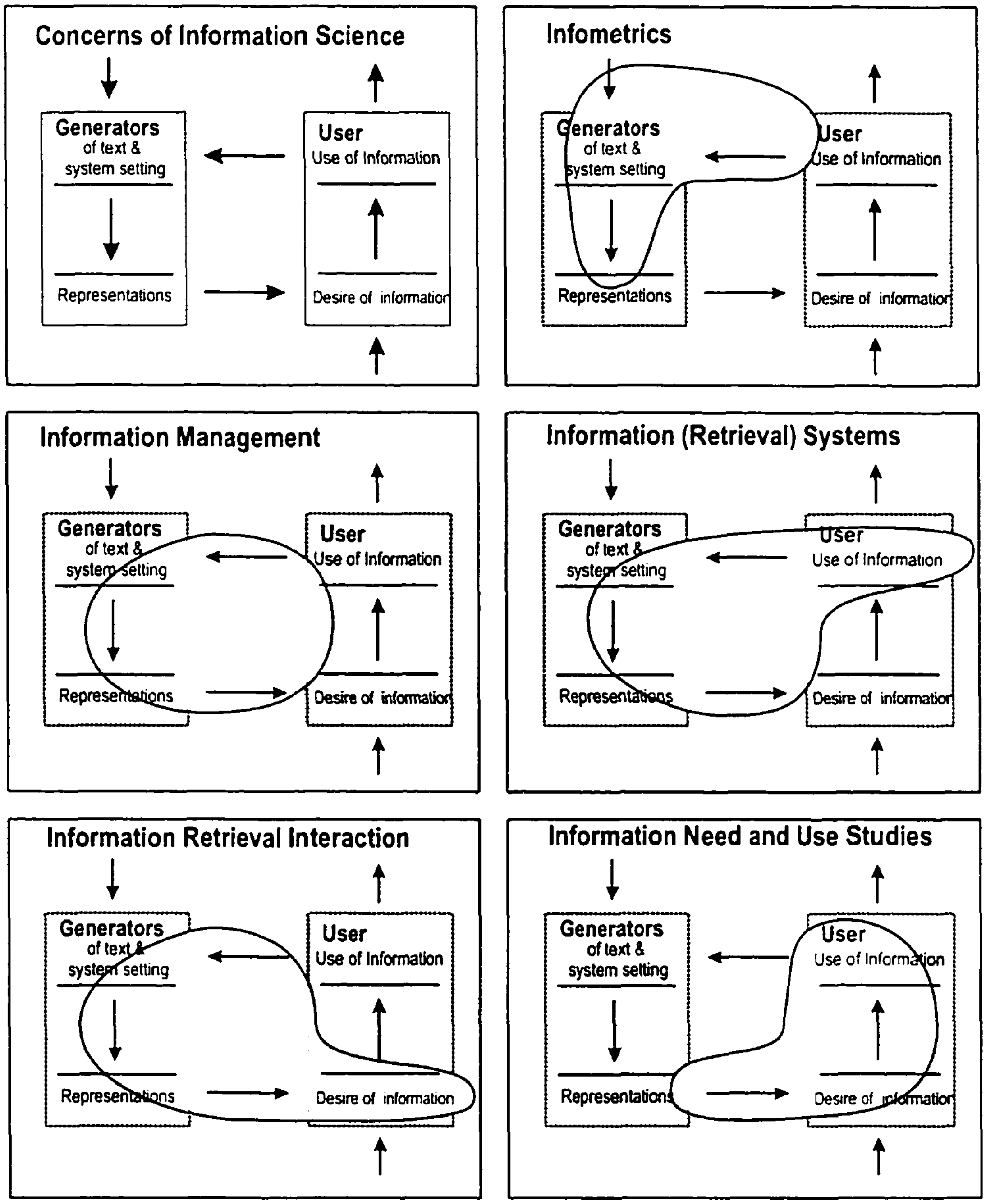

Figure 2.2: **Information Science's constellations of interests:** Illustration based on Partti Vakkari's description of Ingwersen's illustration of Information Science emphases. (Ingwersen, 1992) and (Vakkari, 1994, p 41)

in a "single" discipline. I have included the diagram in Figure 2.2 in this thesis in order to compare its similarities with diagrams of the field of Informatics, and HCI itself. For example, the inclusion of the user within the possible constellation of interests of information science goes beyond the models used to describe Informatics' disciplinary matrix. In HCI, besides the user and the artifact, the context and the development process is also depicted, going beyond this diagram.[8]

Among the several areas that HCI both encompasses and depends on, disciplinary niches such as Human Factors, Human-Computer Interaction itself, Computer Supported Cooperative Work, Computer Mediated Communication, and others already mentioned are loosely linked with each other. Similarly to Informatics, when some of these areas are often considered part of HCI, others are not, having distinct disciplinary identities. It is their relationships, including closely knit and loosely related topics, that forms HCI's disciplinary cultural ecology.

Some topics and perspectives across HCI are restricted to specific disciplinary niches, but others depend on inter-disciplinary scaffolds. The differences and similarities between them, the tendencies to increase or decrease disciplinary breadth and depth vary across history. I understand that a conceptual model of disciplinary cultural ecologies should be expressive enough to depict such factors.

In Table 2.5 I have grouped examples of work that have discussed HCI's interdisciplinary relations with the cognitive sciences, engineering, computer science, information systems, design, computer supported cooperative work, computer mediated communication, and anthropology (ethnography). The fact that these authors have clearly expressed and identified different niches is an indication of the actual disciplinary segmentation. Each of the disciplinary boundaries or bridges used by these authors to differentiate areas or propose new ones in part trace the actual disciplinary

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[8] Several reflections can be made about how further Informatics need to extend its scope and its foundations in order to be really human-centered, and how biased it still is in favor of the isolated artifacts it produces, and against the context it intervenes. For example, today what is known as theory of computing does not include theoretical reflections about communication, language and tool use, privacy, and organizational, social, and ethical issues.

The relation between disciplinary niches across HCI sometimes reinforce, other times blur, their frontiers and links. The link between the cognitive sciences and HCI, for example, has been discussed in (Reitman Olson and Olson, 1990). John Carrol (1991) organized a collection in which several aspects of the relation between Psychology and HCI were discussed, including a discussion of the cognitive sciences (diSessa, 1991), and theoretical approaches (Barnard, 1991). Lewis discussed different conceptions of cognition (inner and outer) and their influence in HCI (Lewis, 1991).

In the academic setting, disciplinary diversity is difficult to foster and sustain. It is difficult, for example, to teach psychology to a computer scientist (Green et al., 1996)(Mantei-Tremaine, 1998), or to show the appropriateness of different approaches and methodologies that address different requirements of information systems (Kuutti and Bannon, 1993).

Susan Leigh Star approached Information Systems through Symbolic Interactionism and Activity Theory, approaches developed in sociology and psychology, respectively (Star and Ruhleder, 1994; Leigh Star, 1995). Raeithel worked on the interface between CSCW and ethnography (Raeithel, 1996). See also Bowker et al. (1997) for a collection in which the relation among the social sciences, technical systems, and cooperative work are discussed.

Team work is a key issue for engineering when projects cannot be done individually. Grudin (1991b), Grønbaek et al. (1993), and Poltrock and Grudin (1998) discussed how a bridge between Computer Supported Cooperative Work and Engineering can help the development of software that supports teamwork. Blumenthal (1995) discussed the relation between industrial design and activity theory. See also Raeithel (1992) and Ribeiro dos Santos and Merkle (2001) for a link between Activity Theory and Design.

Liam Bannon has studied HCI's interdisciplinarity deeply, including the drift of certain niches across time and space. He discussed different cognitive and social approaches in (Bannon, 1991) and (Bannon and Shapiro, 1994); disciplinary trajectories in (Bannon, 1990; Bannon and Schmidt, 1991); and the differences among HCI, CSCW, and Computer Mediated Communication (CMC) in (Bannon, 1992b; Bannon and Hughes, 1993; Bannon, 1997).

I understand that a conceptual model of HCI's nature should be able both to indicate these differences or tendencies across HCI's disciplinary cultural ecology and graphically depict it.

Table 2.5: **Links and frontiers across HCI' disciplinary niches**: examples

heterogeneity found in HCI. A challenge I have undertaken in this thesis is to make sense of them with the aid of a conceptual framework.

Cognitive Science is also heterogeneous. Herbert Simon described it as "an amalgam of artificial intelligence, cognitive psychology, and linguistics, with a few other trace substances (e.g., anthropology, epistemology) thrown in." (Simon, 1995).[9] Francisco Varela included Neuroscience, Cognitive Psychology, Artificial Intelligence, Linguistics, and Philosophy as contributors to the disciplinary matrix that structures Cognitive Science.

The main schools of thought present in the Cognitive Sciences are Cognitivism and Connectionism.[10] Cognitivist and connectionist approaches originated in 1950s. Connectionism is often characterized as emergent (bottom up) because its models usually stress processes that go from particular cases to general ones. In a reverse direction, Cognitivism goes from goals and reasoning to particular cases. Without entering into the details, the main hypothesis of Cognitivism states that the human mind can be modelled as an abstract symbolic computing machine. While the link between computer science (artificial intelligence) and cognitive psychology has been a important scaffold for the development of cognitivist approaches, connectionist approaches have been mainly supported by bridges across neuroscience and computer science. With respect to the cognitive sciences, only cognitivism has had a major impact on HCI.

A third school of thought that emerged in the seventies, also has origins in the cybernetic perspectives developed earlier, remained at the outskirts. Humberto Maturana and Francisco Varela proposed that life, and in consequence cognition, could be understood only through self-organizing, or self-producing mechanisms. They characterized such systems as autopoietic (Maturana, 1975; Maturana and Varela, 1979).[11]

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[9] See also (Gardner, 1985, p 37)

[10] For an introduction to the Cognitive Sciences see Gardner (1985) and Andler (1992). For a comprehensive source, see Wilson and Keil (1999). For examples and a discussion of its role in HCI, see Norman (1986), Bannon (1990), Reitman Olson and Olson (1990), and diSessa (1991)

[11] For a recent appraisal see Mingers (1990, 1995). In HCI, an influential book in CSCW by Winograd and Flores (1990) indicated autopoiesis and hermeneutics as possible foundations for

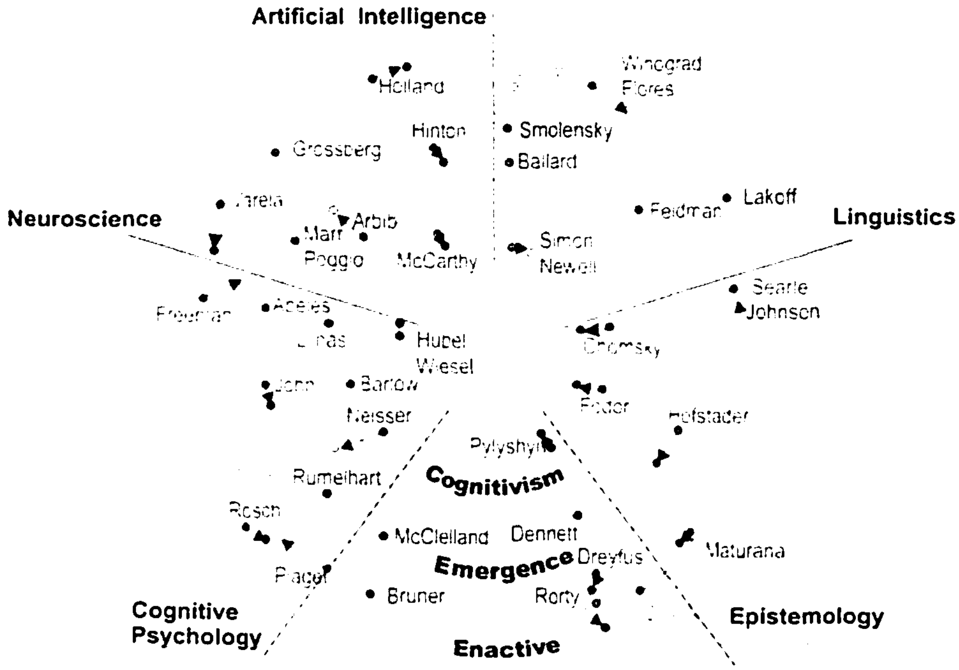

Figure 2.3: **Comparison of Varela's conceptual charts of the Cognitive Sciences**

More recently, Varela called his approach Enactivism (See Varela et al., 1991, p 7).

I have included this brief discussion about the cognitive sciences in order to introduce a second diagram proposed in the literature. In order to differentiate cognitive sciences' paradigms, Varela elaborated a polar diagram to plot authors in relation to different disciplines and different paradigms within the cognitive sciences. Between 1988 and 1990, Varela published at least three versions of this polar diagram.[12] I should remark that in Varela's original diagrams, only dots represent the relative "coordinates" of each author. The diagram on Figure 2.3 depicts the approximate rel-

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an understanding of computers, cognition, and design. Some have characterized this approach as second-order cybernetics (Brier, 1995)

[12] See the diagrams (Varela, 1988, p 168), (Varela et al., 1991, p 7) and (Varela, 1990, p 119). Varela has not discussed the coordinates of each author, or the differences across diagrams.

ative variations of coordinates in three instances of Varela's conceptual polar charts.[13] Independent of the motives behind these variations depicted in Figure 2.3, the use of trajectories to describe these changes enable the graphic representation of the historical transformations that a discipline, a topic, or even a person have undergone. For example Neisser moved from a cognitivist to a emergent paradigm, and Johnson moved from philosophy to linguistics. I understand that Varela's diagrams are limited to approaches in the cognitive sciences that are restricted to the individual organism. This is understandable considering the niche that the cognitive sciences have specialized in. As Howard Gardner wrote:

> 1985 Howard Gardner
>
> *The Mind's New Science: A history of the cognitive revolution* (Gardner, 1985, p 41)
>
> Though mainstream cognitive scientists do not necessarily bear any animus against the affective realm, against the context that surrounds any action or thought, or against historical or cultural analysis, in practice they attempt to factor out these elements to the maximum extent possible. So even do anthropologists when wearing their cognitive science hats. These may be a question of practicality: if one were to take into account these individualizing and phenomenalistic elements, cognitive science might become impossible. In an effort to explain everything, one ends up explaining nothing.

As with Informatics, I understand that traditional cognitive sciences have made key contributions to HCI consolidation. That does not mean that the cognitive science (or whatever other single) approach is sufficient to sustain the development of HCI in the long run. Recent approaches such as Distributed Cognition, Situated Action, Activity Theory, and Language/Action go beyond individual cognition and explore environmental, communicative, dialogical, anthropological, social, historical, cultural, ethical, political, and axiological factors and perspectives.[14]

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[13] From the diagrams, it is impossible to determine if the small differences are due to actual changes in orientations of the respective authors, in differences in Varela's opinion's about these authors, or on differences introduced by whom draw them.

[14] See (Hutchins, 1995; Hutchins and Klausen, 1996) for Distributed Cognition, Suchman (1987); Clancey (1997) for Situated Action; Kuutti (1996)Kaptelinin (1996), and Nardi (1996a) for Activity

Terry Winograd has been calling for a renewal of HCI's traditional foundations since the mid eighties. Winograd and Flores discussed, for example, the use of autopoiesis, hermeneutics, and speech acts to ground a deeper understanding of cognition and design, as I footnoted earlier (Winograd and Flores, 1990). Now I turn to a conceptual chart of language studies that makes use of both delimited regions and arrows to indicate disciplinary influences.

A disciplinary diagram that actually makes use of something like Varela's polar chart, the arrows I introduced in it to depict relations, and delimited regions which I added to Ingwersen's diagrams of information science has been proposed by Halliday (1987) to describe the field of language studies.[15]

Peter Bogh Andersen has contextualized the field of Computer Semiotics in relation to Halliday's disciplinary diagram of linguistic studies (Andersen, 1990, p 18). The diagram in Figure 2.4 depicts the merging of Halliday's and Andersen's diagrams.[16] Andersen illustrated the field of computer semiotics within a region closer to the foci in which language is construed as a system. This region is close to the region in which language is construed as behavior and as artifacts, and it is far from language construed as knowledge. Andersen listed several disciplines related to HCI as surrounding language studies. He clearly remarked that "the distribution of center and periphery was not to be taken as an assessment of their importance; *it [was] simply a portrait of the specific perspective of semiotics, indicating its particular strengths, weaknesses, and its possibilities of collaboration.* (Andersen, 1990, p 19). Andersen's diagram also illustrates the use of curves to depict niches of interest of a certain discipline in respect to a disciplinary space, and how, although delimited, the niche remained open to its milieu.

Theory; and Winograd and Flores (1990) and De Michelis and Grasso (1994) for a Language Action perspective in HCI. See Nardi (1996b) for a comparison of them. In the MIT Encyclopedia of the Cognitive Sciences published in 1999, several entries discuss some of these factors and the respective areas (Wilson and Keil, 1999).

[15] Halliday's approach to language is known as systemic functional linguistics.

[16] In that work, Andersen's approach to language followed a traditional area known as Glossematics developed by Louis Hjelmslev (1975).

The disciplinary diagrams I presented in this section are structured around the relative placement of subject matters, of specific authors, and of orientations or trajectories. They are examples of how to characterize disciplinary niches and their interests. I return now to the nature of HCI, and focus on its models.

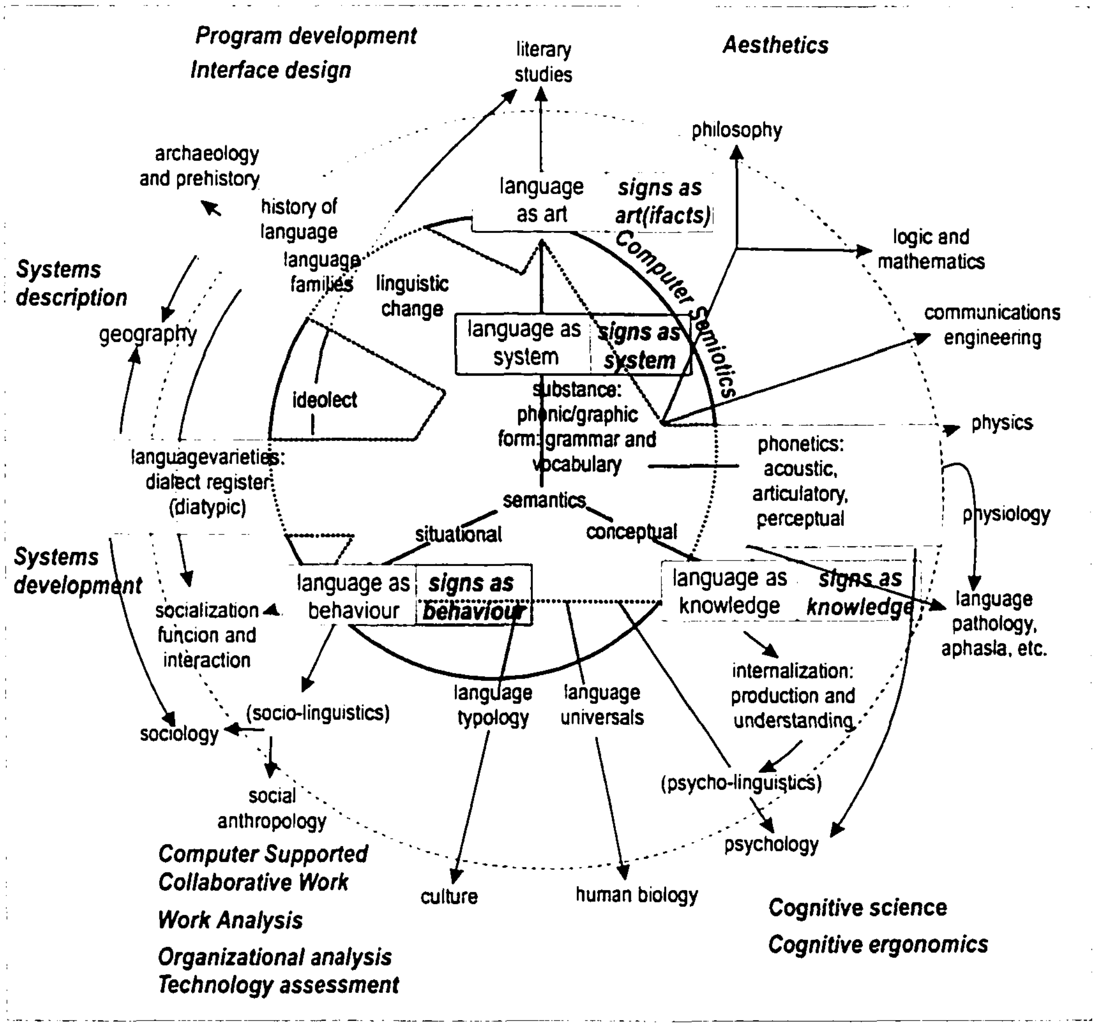

Figure 2.4: **Disciplinary conceptual chart of computer semiotics.** Based on (Andersen, 1990, p 18) and on (Halliday, 1987, p 11).

De Souza (1993) developed an approach called Semiotic Engineering in which artifacts are understood as messages from designers to users. De Souza (1993) graphically depicted the conceptual space of Semiotic Engineering with the aid of Umberto

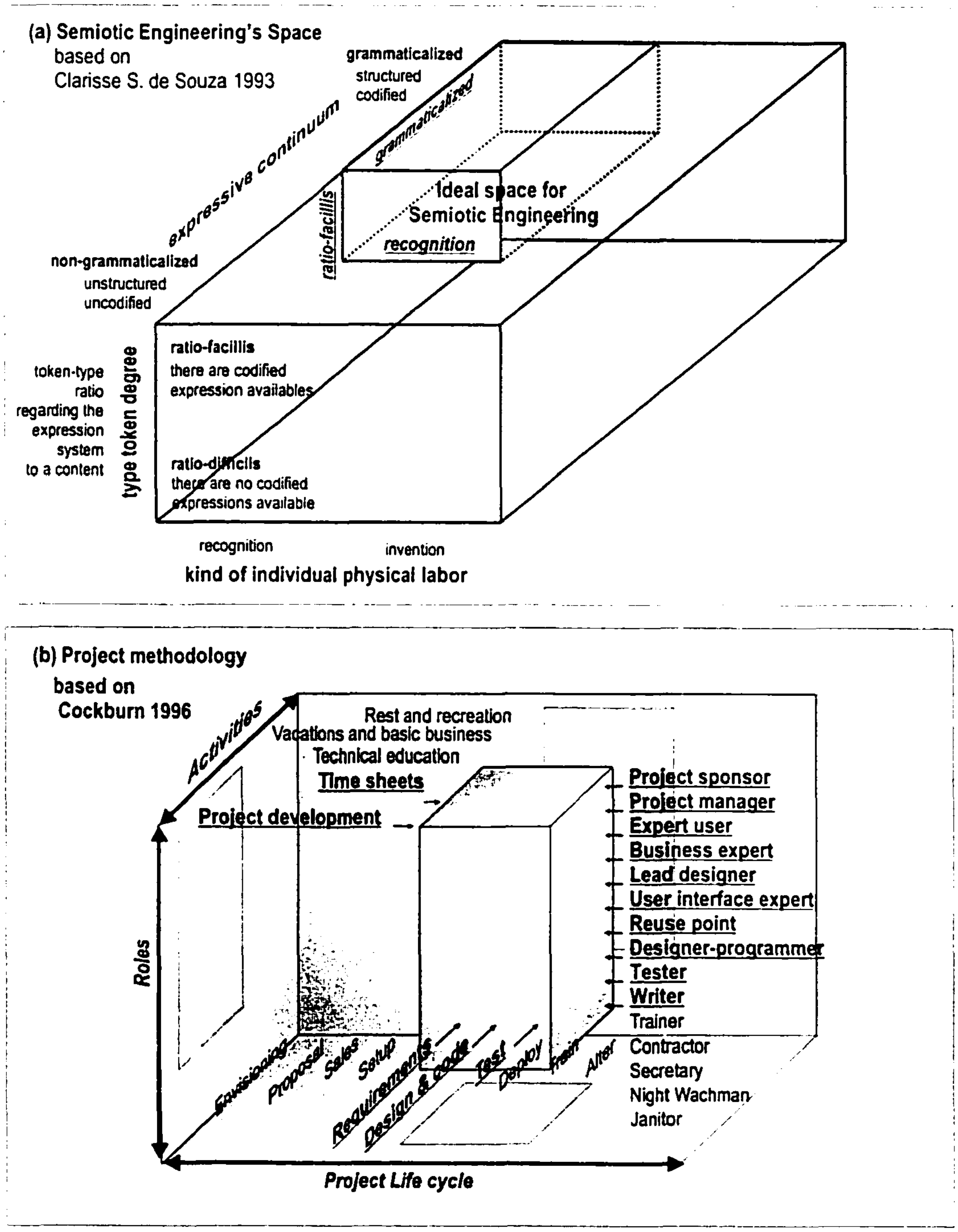

Figure 2.5: **Domain niches and methodologies do not always intersect:** (a) Semiotic Engineering space; based on de Souza (1993) (b) Based on Cockburn (1996)

Eco's approach to semiotics (Eco, 1980), as illustrated in Figure 2.5(a). [17]

Cockburn (1996), for example, discussed the interaction of social issues in software architecture. He addressed how methodologies differ in relation to different stakeholders. Cockburn (1996) made use of three dimensions associated, as illustrated in Figure 2.5(b), with: (a) people roles, (b) project lifecycles, and (c) people's activities; in order to show that domain niches and methodologies do not always intersect. Cockburn's model also exemplifies the need of broader perspectives in Informatics. What is in the foreground of a user-interface expert, for example, is not necessarily the same of what is in the foreground of a secretary, but both can be crucial elements in project development.

2.5 Computers + Humans

In this section I discuss the nature of HCI using as data the expressed opinions of leading researchers in HCI, as well as diagrams of its nature presented in the specialized literature.

In particular, I discuss a diagram included in the SIGCHI Curriculum, its transformations across different versions, and its limitations. Later, I propose an extension of this model considering a more comprehensive description of HCI's nature.

Compared with Informatics, formal education in HCI has started very recently. Most research is done across university departments due to HCI's interdisciplinary profile. There are only a few undergraduate programs in HCI.

Throughout the process of consolidation of HCI, professionals and related associations have discussed how to define it, and how to structure its formal education.[18] One of the groups that has done a significant work in this direction is the ACM Special Interest Group on Computer Human Interaction.

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[17] De Souza's research group has used Peirce's semiotics, instead of Eco's, in their more recent work. See Leite (1998), Prates (1998), and Prates et al. (2000).

[18] See Appendix C for a chronological list of several publications related to education, research, and development in HCI. The list is not complete and is intended only to give the reader a sense of historical continuity.

ACM SIGCHI Curricula for Human Computer Interaction was published in 1992. The respective committee addressed the definition of HCI and the scope of the recommendations in the following way:

1992 Thomas T. Hewett et al.

ACM SIGCHI Curricula for Human-Computer Interaction

(Hewett et al., 1992, pp 5-7, emphasis in the original)

There is no currently agreed definition of the range of topics which form the area of human-computer interaction but [. . .] on behalf of a characterization of the field the following work definition was given as a springboard for their task of establishing a curricula:

> *Human-computer interaction is a discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them.*

[. . .] But it is clear that varying what is meant by *interaction*, *human*, and *machine* leads to a rich space of possible topics [. . .] In this report, we have adopted, as a ACM committee, an appropriate computer science point of view, although we had tried at the same time to consider human-computer interaction broadly enough that other disciplines could use our analysis and shift the focus appropriately.

The use of the term "surroundings" to define the contents of HCI is similar to Newell, Perlis, and Simon's computer science definition quoted in Chapter 1, which stated that "Computer science is the study of the phenomena surrounding computers" (Newell et al., 1967, p 1373). However, there is an additional human element in the basic unity of analysis of HCI. In relation to Gibbs and Tucker's definition for liberal arts programs (Gibbs and Tucker, 1986), the above definition has the same flexibility, enabling the characterization of different niches.

The ACM committee included in the SIGCHI curriculum a diagram depicting the nature of HCI. Instead of presenting directly the model of HCI as published in the 1992 report, I start with an earlier diagram published in 1991, depicted in Figure 2.6. In a series of initiatives to structure education in HCI,[19] Marchionini and Sibert

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[19] Earlier examples related to HCI education included Verplank and Kim (1986), Mantei (1989).

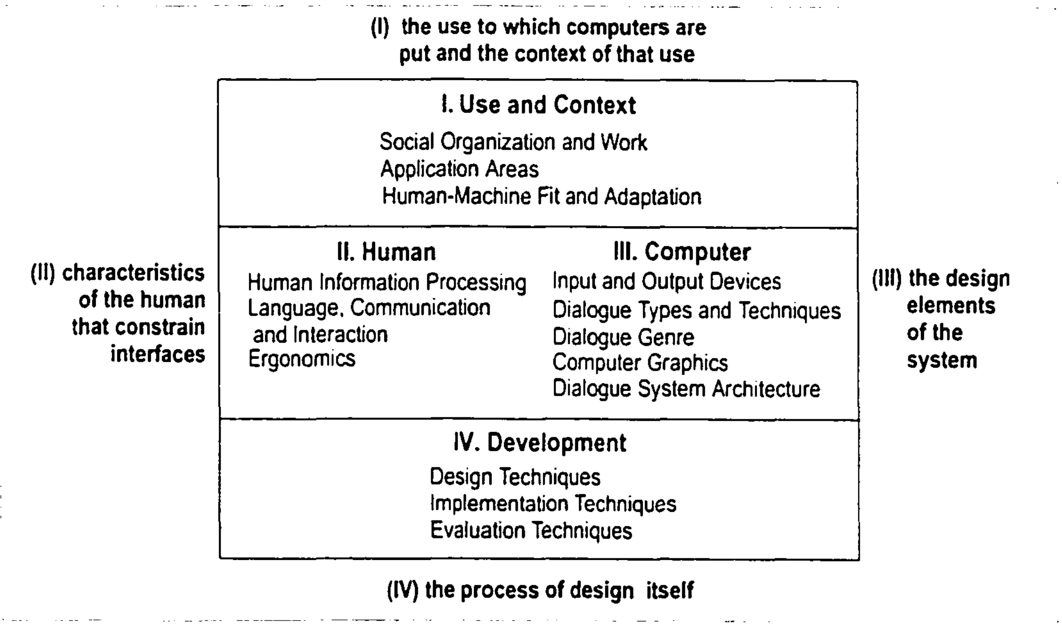

Figure 2.6: **Marchionini and Sibert's chart of HCI's nature.** (Marchionini and Sibert, 1991, p 20, redrawn)

published an agenda for HCI in the SIGCHI bulletin in which a sketch of SIGCHI's diagram was initially presented. Marchionini and Sibert characterize HCI's domain as involving a combination of topics related to: (i) the use to which computers are put and the context of that use; (ii) the human characteristics that constrain interfaces; (iii) the design elements of the system; and (iv) the process of design itself. They detailed each of these four items in several sub-topics and presented them in a diagram similar to the inner rectangle depicted in Figure 2.6.

The actual SIGCHI Curricula for HCI report was published in 1992 (Hewett et al., 1992). William Verplank and Stuart Card developed a graphical representation for the corresponding topics of the nature of HCI. Verplank and Card's diagram is depicted in Figure 2.7's top diagram. I have redrawn it in order to facilitate a parallel with the other diagrams. The associated description in quoted in Table 2.6.

A third and a fourth diagram were published in reports from a workshop discussing

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Perlman (1989), Strong (1989), Perlman (1990), and Preece and Keller (1990), but are not restricted to these ones.

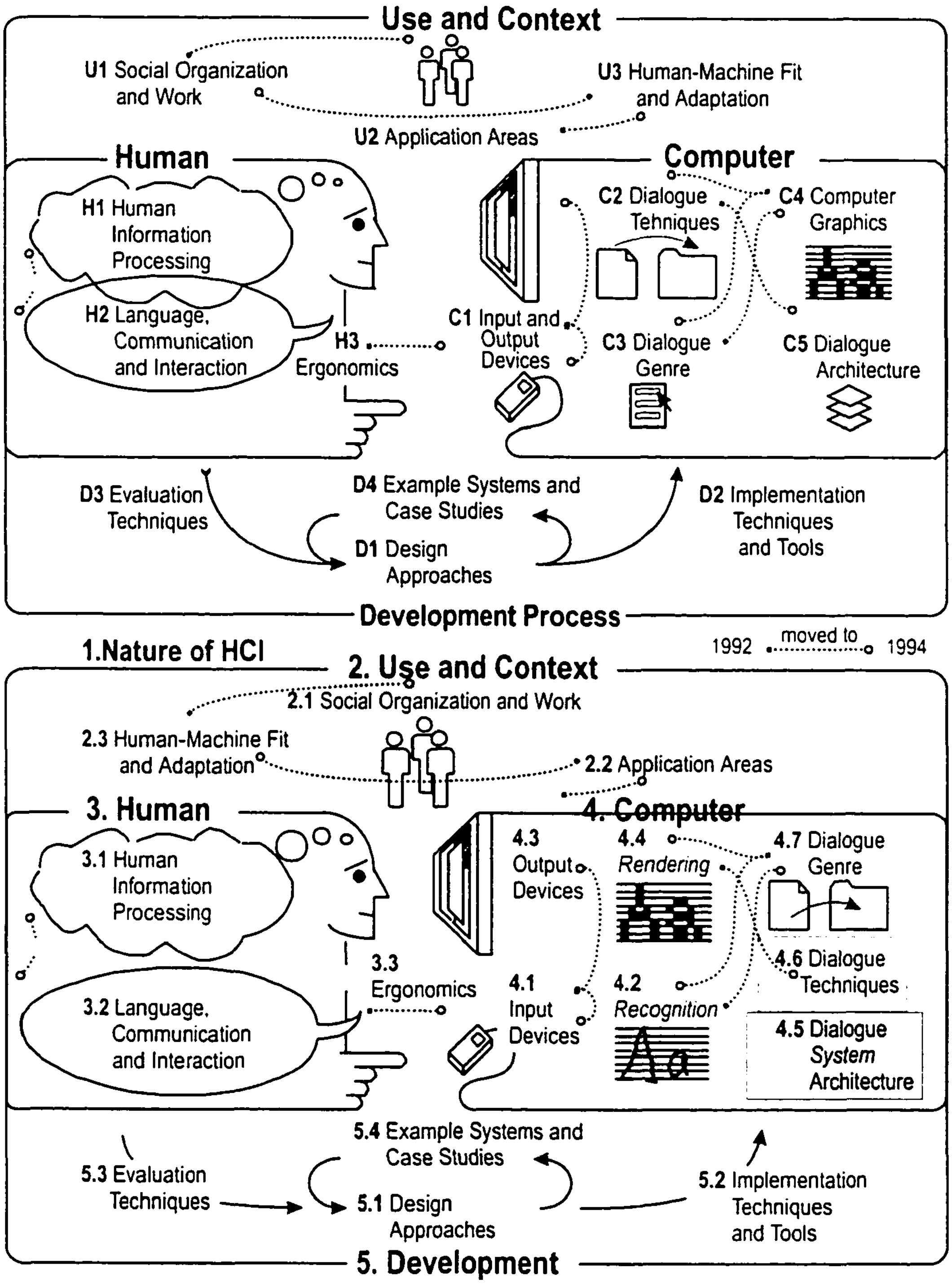

Figure 2.7: **The nature of HCI compared:** Top: (Hewett et al., 1992, p 73, redrawn) Bottom: (Strong et al., 1994, p 15, redrawn)

1992 Hewett et al.

ACM SIGCHI Curricula for Human-Computer Interaction

(Hewett et al., 1992, pp 14-17, reformatted, emphasis and comments added)

(N1)[**The Nature of Human-Computer Interaction** includes:]

[T]he use and social context of computers:

(U1) Computer Systems exist within a larger [cultural] *social, organization and work* milieu.

(U2) Within this context there are *applications* for which we wish to employ computer systems.

(U3) But the process of putting computers to work means that the human, technical, and *work aspects of the application situation must be brought into fit with each other* through human learning, system tailorability, and other strategies.

[On] **the human [characteristics]** we must also take into account

(H1) human *information processing*, [or cognitive and affective system]

(H2)*communication* [or mediating artifacts such as language and gesture], and

(H3) the *physical* [ergonomic and cognitive] characteristics of users [people interacting with machines]

On **the computer [system and interface architecture]**, a variety of technologies have been developed for supporting interaction with humans:

(C1) *Input and output devices* connecting the human and the machine [or interactive devices].

(C2) These are used in a number of *techniques for organizing dialogue* [including dialogue inputs and outputs, interaction techniques and other issues].

(C3) These techniques are used in turn to implement larger design elements, such as the metaphor of the interface [*dialogue genre*]

(C4) Getting deeper into the machine substrata supporting the dialogue, the dialogue may make extensive use of *computer graphics* techniques, [including *rendering* and *recognition*].

(C5) Complex dialogues lead into considerations of the *systems architecture* necessary to support such features as interconnectable application programs, windowing, real-time response, network communications, multi-user and cooperative interfaces, and multitasking of dialogue objects.

Finally, there is the **process of development** which incorporates:

(D1) *design* for human-computer dialogues [interaction],

(D2) *techniques and tools* for [specifying and] implementing them,

(D3) *techniques for evaluating* [and monitoring] them, and

(D4) a number of *classic designs* [and case studies] for study.

Each of these components of the development process is bound up with the others in a relationship of mutual, reciprocal influence whereby choices made in one area impact upon choices and the options available in the others.

Table 2.6: **SIGCHI's description of the contents of HCI** (Hewett et al., 1992, pp 14-17, reformatted, bold added)

HCI's new directions.[20] The third diagram has some differences from the 1992 one, which was included in the SIGCHI Curriculum. In Figure 2.7, the dashed lines indicate the changes between the 1992 and the 1994 versions.[21]

Contrasting the first diagram (Marchionini and Sibert) in the series of four with the second (SIGCHI Curriculum), "development processes" have been complemented with "example systems and case studies". This change may appear simple, but it is not. As the committee remarked, choices in one area have repercussions in the other ones, and vice-versa. I should remark that case studies and classic designs are not explicitly recognized in Informatics as methodologies, with the exception of the branch of information systems management.[22] [23]

The graphical representation of the second, third and fourth "SIGCHI" diagrams added the possibility of grouping the topics through relative placement. One of the particularities of the graphic representation used in these diagrams is that the topics involving either single individuals or single computers have been emphasized once their boundaries have been delimited and their graphic representation has been added.

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[20] See (Strong et al., 1994, p 15) for the full report and (Strong, 1995) for an abridged version describing the workshop activities.

[21] I should remark that in both the SIGCHI Curricula (Hewett et al., 1992) and the New Foundations Workshop report (Strong et al., 1994) the committees and the participants included a conceptual inventory of HCI and remarked that these diagrams were able to depict only a subset of the actual relationships among the listed topics.

[22] Informatics' everyday practice, however, makes extensive use of examples and actual approaches, both in theory and in practice. For example, a work that became classic has been structured around classic algorithmic solutions for a wide variety of problems is Donald Ervin Knuth's three volumes of the "The art of computer programming", first published in 1968, 1969, and 1973, respectively (Knuth, 1998). The joint use of examples and case studies historically contextualizes the appropriateness of a certain solution to a certain problem. Case studies and history give the technology stakeholders a scaffold from which to structure their interventions.

[23] The concept of software patterns, for example, when understood in the full breadth that it deserves, fosters a systemic human-centered perspective to software design and re-use. It is structured around contextualized archetypal examples. See Coplien (1997) for a brief but critical overview of the uses and misuses of software patterns.

In the third diagram of HCI's nature in a series of four (Strong et al., 1994, p 15), the "social and organizational work" related topics moved higher and to the center. In the light of the metaphor that says that what is higher is broader (Lakoff and Johnson, 1980), this relative placement is in accordance with the textual description of the second diagram (U1, which includes U2, which implies U3) (Hewett et al., 1992, pp 14-17)
"Application areas" moved closer to the computer. This is in consonance with the common meaning ascribed to "application" in Informatics. This can be questioned in the light of usability studies and human centered perspectives, in which the development of applications is contingent on human practices and should be centered on them.
"Human-machine fit and adaptation" moved closer to the human. This may reinforce the traditional view that the human is the one who needs to adapt, and not the machine that needs to be adapted by the human. In the model I propose later, I have maintained the above three topics stacked as in the first original diagram.
The main change in the "human" topics is the drift of Ergonomics from the human boundaries to the center of the diagram, between the human and the computer. This is in accordance with the area of human factors (or ergonomics, as known in Europe) which has its focus on the relation between humans and machines. In the model I propose later, I add a third region in the center where I group elements that necessarily depend on the relation between humans and mediating artifacts.
A minor change that may have deep implication is an increase in the distance between "human information processing" and "language, communication, and interaction". This split is in accordance with the tenets of traditional cognitive science (cognitivism). However, dichotomies such as mind and body, subject and object, "langue" and "parole" have been criticized by schools that do not accept this division. I understand that a model of HCI's nature should be less biased and use terms that enable developments in different paradigms.
On the computer side, its reorganization reflects the main models that describe the traditional flow of information within a computer, from input to output devices. Input and output devices are now separated, and computer graphics is subdivided into recognition and rendering. In times of ubiquitous and mobile computing, in which the division of input and output devices becomes increasingly blurred, this choice may be not the best option. Dialogue genre, dialogue techniques, and dialogue system architecture form now a hierarchy that resembles higher to lower level issues used to describe the technical scale discussed earlier. The 1992 placement of genre was placed under dialogue techniques. I would rather place genres at the center.
The circular flow of information between human and machine has been reinforced in a fourth diagram (Strong, 1995, p 71).

Table 2.7: **Differences between SIGCHI's and New Direction's diagrams**

The main differences between the second and the third versions include a reorganization of the topics related to the *use and context*, a reorganization and refinement of topics related to the *computer*, and a transfer of the *ergonomic factors* to a place in between the human and the machine.[24] I have not explored the several possible motives and consequences associated with each of these changes. Nevertheless, the topics associated with the computer system reached a higher level of detail and structure than the human side, but the focus on individual cognition and individual computer remained, reflecting the emphasis of the committee on computer science. It also reflects what was understood at the time as computer science and cognition, and on what the committee agreed were at HCI's center and periphery. I have grouped my opinions about some of these placements in Table 2.7.

These diagrams and their transformations reflect the historical disciplinary tendencies as crystallized in HCI and supported by traditional views in psychology and in computer science. Indeed, the representation may have facilitated the adoption of the diagram by those at the center of the discipline.

The explicit inclusion of the user, as well as of contextual and developmental issues goes beyond the similar models used to characterize the nature of Informatics, which have been product centered. I understand that there is gap between this model and the current topics, contents, and methodologies of HCI as understood broadly. In the next section, I present some models that stress distinct issues across HCI's domain models in order to propose an alternative graphic representation.

I have presented the two layered model depicting Peter J. Denning's IT professions in Chapter 1 in order to organize a human side of information technology. In this section, I further subdivide this human dimension, and illustrate it with a continuous scale that depicts, for example, from the small biological molecules that compose life and are being used in molecular and biocomputing to the large groups of people that can be affected by information technologies across societies.[25]

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[24] Considering the inventories included in these reports, it is my opinion that the third diagram is the one that reflects the most of their contents.

[25] I emphasize again that the mapping of topics and respective disciplines does not demarcate their

The respective disciplines with emphasized foci and boundaries across this human dimension are those with subject matters related to life and human sciences. They are usually housed in the faculties of science, health and social sciences. For example, Biology and Plant Sciences are usually in the sciences, but Physical Therapy and Medicine are usually in the Medical Sciences. Psychology, Anthropology, Sociology, Economy, and Political Science are examples of disciplines in the Social Sciences. I have not explored the historical and intellectual roots of these disciplines. Examples of areas that conceptually bridge disciplinary boundaries along a single dimension are social-psychology (individual and society), neuro-psychology (individual and human physiology), and biological and cognitive anthropology. Examples that further segment them are based on distinctions such as low and high-level cognition, or macro-social and micro-social phenomena.[26] I proceed now with a correlation of a technical and a human dimension.

Figure 2.8 depicts the main areas across the field of HCI understood broadly in reference to the human and the technical dimension, as introduced here. The ellipses sketch the traditional foci of Human Factors, Human-Computer Interaction, Computer Supported Cooperative Work, and Sociotechnical Systems.[27] I remark that Figure 2.8 is a conceptual abstraction, the boundaries are only illustrative.

A correlation between the number of computers and the number of people is depicted in Figure 2.9. The examples show the different foci that Informatics has had

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"territories". The continuous nature of the scales proposed here are intended exactly to enable the representation of different opinions about where a field starts and finishes, or what it emphasizes or de-emphasizes. Indeed, each mark, representing a boundary or a bridge, may depict agreement or disagreement.

[26] I would do not include in these group areas such as bio-informatics, industrial psychology, socio-technical systems, because they stress a technical and a human dimension simultaneously. Linguistic anthropology, socio-linguistic also stress a communicative dimension.

[27] See Sanders and McCormick (1987) for a classic book in human factors in engineering and design, Card et al. (1983), Baecker et al. (1995), and Helander et al. (1997) for HCI, Greif (1988) for CSCW, and Coakes et al. (2000) for sociotechnical systems. For references on historical transformation across and among these fields see (Bannon, 1990; Bannon and Bodker, 1991; Bannon, 1991, 1992b, 1997), and (Grudin, 1991b, 1993, 1994a, 1998)

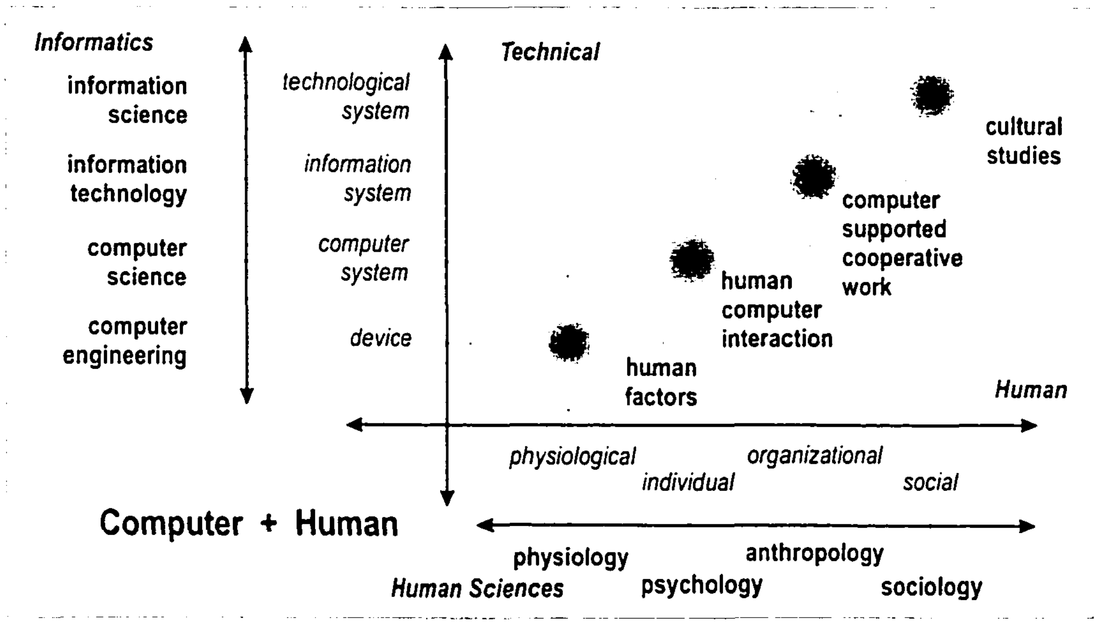

Figure 2.8: **HCI's specialization across human and technical strata**

across its historical development. In Figure 2.9(a) I have depicted the professional relations described by Teichroew among programmers, systems designers, and information analysts (Teichroew, 1971, p 577) in the context of information systems management education. With a two dimensional representation it is possible to depict who is interested in parts of the computer, who is interested in the performance of the whole system, but not in its users, or who is interested in the organization itself.[28]

To further illustrate the expressiveness of the diagram, I have depicted on Figure 2.9(b) archetypal regions of areas such as: (a) bio and molecular computing, (b) mainframes and timesharing with one computer and multiple users (c) isolated gismos and technological gadgets (d) the isolated personal computer (PC), (e) embedded devices such as pacemakers that interact with specific organs, (f) the use of many computers by one single person, and (g) the use of multiple computers by many persons simultaneously. I remark that the use of scales does not imply that the boundaries of each discipline should necessarily be ordered in the same way as

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[28] Teichroew used both a linear scale and a table to describe such relationships. See Figure 1.4(a).

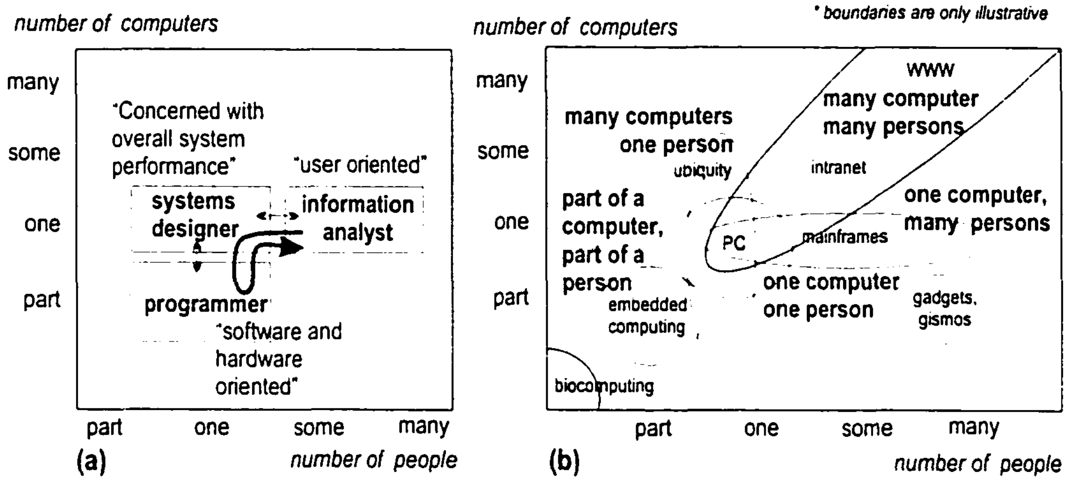

Figure 2.9: **Correlating the human and the artificial: people and computers**

their foci. Indeed, the early use of the term constellation of interests in intended to avoid the sharp delimitation of disciplinary niches. There is a tendency to pigeonhole disciplinary domains, and in fact, this may be reinforced by representations that do not allow a clear differentiation of their breadth in multiple dimensions.

Indeed, each representation of the boundaries of a discipline is contingent on the adopted point of view. For example, Vakkari (1994) has pointed out that library science is information science in library settings, and consequently the term information science is enough. This may be true in the technical dimension, but the fact that library science is usually associated with a specific kind of organization also implies that it has a different emphasis on the human dimension which has been abstracted away in the technical systemic perspective.

The planar representation depicting the correlation between the technical and the human dimensions does not enable a direct representation of what, how, and why people use technology. However, people use computers *to accomplish tasks* (John and Morris, 1993, p 49): Informatics changes the way organizations *work*: technologies both pollute and influence the course of wars, etc. Gregory Bateson, for example, illustrated the mutual relations among populations, technology, and hubris, and the side effects of pollution, war, and famine, through a diagram equivalent to the one in Figure 2.10(a). A diagram like the ones illustrated on Figure 2.9 would conflate Bateson's diagram to a point in a surface (population and technology) as depicted in Figure 2.10(b).

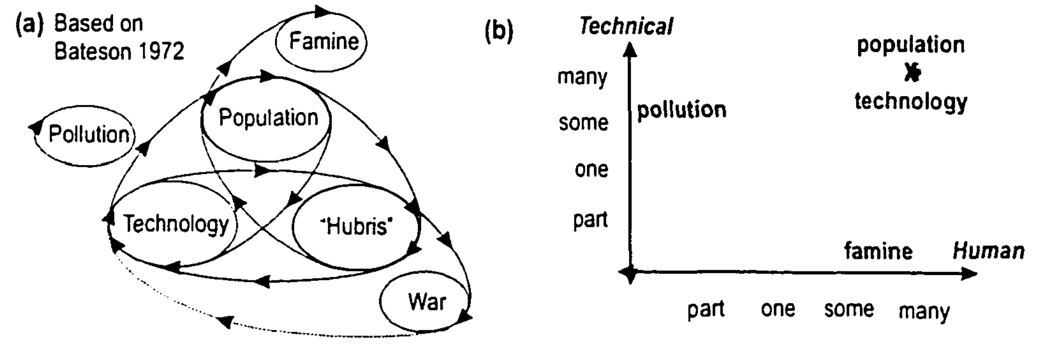

Figure 2.10: **Cultural relations among population, technology, and hubris**, and its sub-products (pollution, war, and famine) (Bateson, 1972, redrawn)

The mechanisms behind the establishment of boundaries and foci across different dimensions is a topic that goes well beyond the scope of this dissertation. In Table 2.8, I added a side comment listing some literature in which the problem of scales, orders, and hierarchies has been discussed across different disciplines.

2.6 Humans + Computers + Interactions

I proceed now with conceptual spaces that make use of three dimensions, instead of two. Some of these spaces are used only to chart the focus of some approaches. Others are used to explore or suggest the dynamics present in them, as in the previous examples.

The models of HCI discussed until now emphasize the individual user and the individual computer. These are not the only dimensions discussed in the literature, and do not reflect current theories, models, practices found in HCI. In the SIGCHI curriculum, in which one of the diagrams of the nature of HCI has been depicted and described, the same committee stressed that HCI professionals should master the technological aspects of computing, the cognitive and ergonomic issues associated

I should emphasize that scales used to chart the multiple facets of HCI are not top-down or bottom up authoritative control orders. Gunderson, Holling and Light mentioned that Herbert A. Simon (1974) was one of the first to argue for the adaptive significance of the manner in which elements of complex systems nest inside one another (Gunderson et al., 1995, p 518).

In Simon's approach, semi-autonomous strata emerge from the interactions (flow of resources) among a set of variables closely knit together. Each level interacts with other levels: a higher and slower one, and a lower and faster one. The strata are semi-autonomous because they can change their organization without changing the whole hierarchy, as long as the interactions with the other levels are maintained.

Ecologists have appropriated Simon's hierarchy to describe ecological systems, but in the long run, perspectives assuming top-down control hierarchies have prevailed, losing the adaptability and resilience offered by the interactions among semi-autonomous strata(Gunderson et al., 1995, p 518).

Salthe has done a detailed study of hierarchical systems in biology with references to semiotics and dissipative structures (Salthe, 1985) (Salthe, 1993). See Allen (1998), Kolasa and Waltho (1998), and Emmeche et al. (1993) for discussions on the inappropriateness of a strict order between levels in ecology and theoretical biology.

See Andersen et al. (2000) for a collection of articles in several areas discussing the relation between minds, bodies, and matter as complex behavior. Upward causation implies that the study of the interactions among the components of a system is enough to explain the system itself. Downward causation implies that the whole influences the components.

I have a preference for a partial order scale. This position is consonant with Jay L. Lemke's studies of social organizations (Lemke, 2000). I do not address in this thesis how disciplinary strata concerns HCI development, facilitating the separation of the macro from the micro, of the component from the system, and the possible advantages and drawbacks of such organizations. It is not only possible to prescind some aspects in relation to others, but necessary, depending on the purpose. I understand that the possibility of disciplinary focus is crucial to disciplinary consolidation in certain phases of its development, but it can become a hindrance in other phases. In Chapter 3, I present some models of organizational change that address part of this dynamics, but the analysis of such dynamics in HCI demands a level of detail that goes beyond the scope of this thesis.

Table 2.8: **On systems scales, levels, and hierarchies**

with its users, and the social and organizational issues associated with the systemic issues (Hewett et al., 1992, p 73).

For example, in Sears' quote (in Table 2.9), he lists four dimensions: people, computing systems, interaction, and usability. People and computer systems are material and their boundaries are easily recognized. But both interaction and usability could be characterized as interactive issues. Similarly, Engelbart's conceptual system had five: humans, language, artifacts, methodology, and training (H-LAM/T). Language, methodology, and training could be all associated with interactive dimensions. I will not attempt to define the fluid nature of action or of processes, but I called this dimension "interactive", in contradistinction to the technical and the human dimension.[29]

Strong et al. (1991) have been even more clear regarding which dimensions HCI should encompass, explicitly listing technical, social, and ethical issues. Andrew Sears expressed that HCI definitions are broadening the scope in which they stress "people, computing systems, interaction, and usability" (Sears, 1997, p 7). Similarly (de Michelis et al., 1998, p 64) proposed a conceptual space for information systems based on three broad areas of concern: a systemic facet, a group collaborative facet, and a organizational facet. Table 2.9 reproduces the respective longer quotes of these authors.

There are several other professionals who have characterized informatics and HCI with the use of more than two dimensions. Some have done it implicitly, others explicitly. The list in Table 2.10 is not comprehensive but it reinforces the view that HCI and Informatics have multiple dimensions, and that they can be compared. It also illustrates how scattered and fragmented the current situation is. Most of the references do not cross-reference each other.

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[29] It is my opinion that no single set of three dimensions and associated scales will ever describe every phenomena related to HCI and Informatics. The introduction of these three particular dimensions should be understood as a projection of multidimensional spaces, involving a multiplicity of factors, voices, interests, scales, forces and related issues. In a future work I would like to explore Bakhtin's work to ground this perspective.

1992 Hewett et al.

ACM SIGCHI Curricula for Human-Computer Interaction (Hewett et al., 1992, p 73)

Ideally, an HCI specialist would be equally comfortable dealing with technological issues, the needs of individuals and the concerns of their organizations and work groups. We know of individual HCI practitioners who have achieved a substantial competence along these lines, but they often express dissatisfaction at their own lack of fundamental grounding outside the discipline they have studied formally. Therefore, we recommended that an interdisciplinary HCI curriculum should develop a sense of mastery in:

- the technological perspective of computing.
- the ergonomics issues at an individual level, from cognitive science to human factors curricula.
- the 'system' issues, from disciplines like organizational science, information systems, or sociology.

The mastery is necessary for political as well as professional issues."

1994 Strong et al.

New Directions in Human-Computer Interaction Education, Research, and Practice
(Strong et al., 1994, p 27)

The study of ethical and social issues in computing is interdisciplinary in nature. Ethicists, historians, social analysts, sociologists, anthropologists, and psychologists have all contributed to research in this area. [. . .] Only analysis that accounts for at least three dimensions – technical, social, and ethical – can represent the issues as they affect computer science in practice.

1997 Andrew Sears

HCI Education: Where is it headed? (Sears, 1997, p 7)

As HCI continues to mature as a discipline, we must continue to question the bounds of the field. We must define what is within the realm of HCI and what is not?'[. . . Each HCI definition] stresses people, computing systems, interaction, and usability. How you interpret these terms determines the scope of the discipline. We will see a broadening of the definition of human-computer interaction to include more flexible interpretations of the terms human and computer.

1998 de Michelis et al.

A Three-Facet View of Information Systems (de Michelis et al., 1998, p 64)

"Dealing with change is one of the most fundamental challenges facing IS [Information Systems] professionals today. [. . .] . The computing field has responded to the challenge and the need of flexibility in a number of ways. .. However, conceptual cohesion [. . .] is still missing. [. . .] We envision that change-related issues for IS arise from three areas of concern – *systems*, *group collaboration*, and *organization*.

Table 2.9: **Three facets of HCI: quotes**

Human	Computer	Interaction	Bibliographic Reference
human	computer	task	(Eason, 1991, p 722)
people use	computers to	accomplish tasks	(John and Morris, 1993, p 49)
psychological view	systems view	interactive view	(Green et al., 1996, p 95)
people	products	processes	(Cowling, 1998)
ergonomic	technological	systemic	(Hewett et al., 1992, p 73)
user experience	technology	marketing	(Norman, 1998)
software use	software engineering	organizational implementation	(Braa, 1995)
customer	product	application	(Moore, 1991, p 100)
how people design	implement	and use	(Myers et al., 1996)
what's desirable?	what's capable?	what's usable?	(Cooper, 1999, p 73)
design	engineering	business	(Moore, 1991, p 100)
conception	construction	communication	(Bertelsen, 1998, pp 48-49)
people needs	tool needs	skill needs	(Nunamaker Jr. et al., 1982, p 783)
information systems	organizations	signs & norms	(Stamper, 1996)
group collaboration facet	system facet	organizational facet	(de Michelis et al., 1998, p 64)
business opportunity	IT architecture	service delivery	(Willcocks and Sykes, 2000, p 35)
user diversity	technological variety	gaps in user knowledge	(Shneiderman, 2000)
customer relationships	product innovation	infrastructure	(Hagel III and Singer, 1999)
customer support	developers	developers	Grudin (1991a)
symbolic interactionism	information systems	activity theory	(Leigh Star, 1995)
social science	technical systems	cooperative work	(Bowker et al., 1997)
social system	technical system	activity	(Henderson and Ehrlich, 1998, p 41)
social system	technical system	organizational task	(Eason, 1991, p 722)
social system	technical system	business function	(Eason, 1997, p 1478)
science	interpretation	change	(Braa, 1995)
human values	technology	design	(Friedman, 1997)
social	technical	ethical	(Strong et al., 1994, p 27)

Table 2.10: **Three facet models across HCI and Informatics:** other references.

Table 2.10 lists each set of three issues from the "narrower" to the "broader", going from "people using computers to accomplish tasks" to the "social, technical and ethical". Therefore, in addition to the three dimensions, scales are also associated with them. Each author, of course, has a constellation of interests that encompass a certain niche within these three dimensions.

As in Chapter 1, the professional boundaries and foci may vary, indicating different perspectives and emphases. Although several of the authors listed on Table 2.10 authors characterize their objects with the aid of three dimensions, sometimes they also sharply delimit the scope of the phenomena associated with each dimension. An example of such delimitation is given by a model proposed by Eason, who used three dimensions and three levels to characterize HCI.

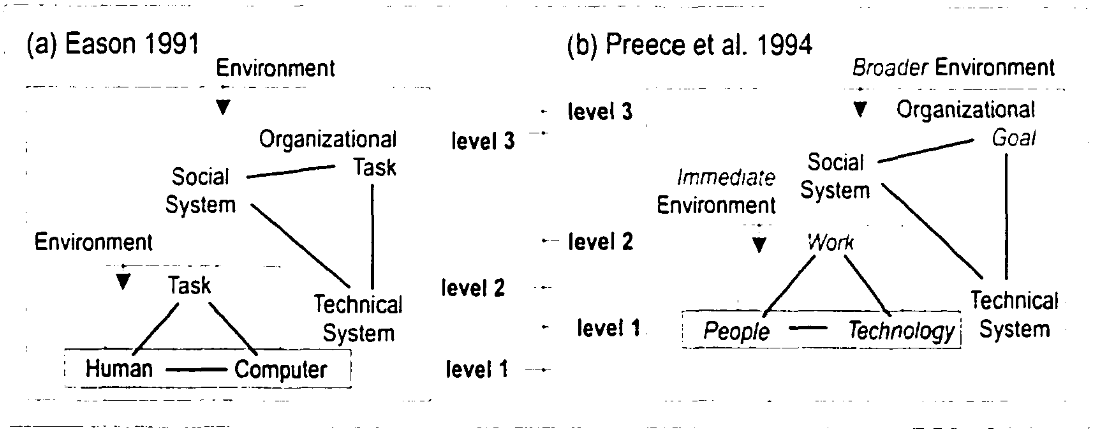

Figure 2.11: **Eason's three facet, three level diagrams of HCI**: (a) Three levels of analysis for HCI reproduced according to K. D. Eason's illustration (Eason, 1991, p 722). (b) As adapted by Preece et al. (Preece et al., 1994, p 44). I have redrawn both diagrams in order to show differences in the levels of abstraction.

Eason graphically characterized ergonomic perspectives in HCI as involving people doing *tasks* with the aid of computers within social systems doing organizational *tasks* with the aid of technical systems. See Figure 2.11(a). He organized the diagram in three layers. Preece et al. (1994) adapted Eason's model to (i) people doing *work* with the aid of computers in the context of (ii) social systems achieving organizational *goals* being supported by technical system. See Figure 2.11(b). But there is a difference of level of abstraction between task and work, and between task and goal. It is impossible however to clearly demarcate when one finishes and the other begins. Professional identities tend to be dichotomized, such as in developers versus final users, researchers versus professionals, individual versus collective. There are several models, professional and organizational, that have attempt to blur this dichotomies. The next section explore models that break up with the barriers that separate the identities and the activities of developers and users of technology in different degrees.

2.6.1 Stakeholders' Relations across HCI

Any profession, as soon as it develops a professional identity, tends to sustain and protect its organization against foreign elements. However, there is a thin line separating the development of sustainability from the development of xenophobia. While the former is open to alterity, the latter is closed to it.

In reference to the cultural ecology of Informatics, or HCI, activities of design, broadly conceived, cut across several disciplinary niches, involving a myriad of stakeholders and spanning through long horizons of time. One of the difficulties of approaching labor/professional-related issues in HCI is that cultural factors have been traditionally excluded from HCI's commonly recognized set of interests. In consonance, those in the social sciences and humanities who have been working with such factors for a long time, and who could contribute with a critical perspective, are alien to the field. A broad perspective has been the exception in Informatics's everyday life, rather than the norm.

A profession continues to exist only as long as its role in society continues to a certain extent to be beneficial to other segments of the same society. If there are no available resources, for whatever reason, the organization and its identity vanishes or changes. An in-depth analysis of these issues involves the dynamics of particular disciplinary and extra-disciplinary relations within and across groups and societies. They are, indeed, part of the cultural ecology of HCI. Professionals should be able to study their on community with the same tools they study other communities.[30]

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[30] See Bourdieu (1990, 1991) for a critical analysis of the social relations involved in everyday

There are many organizational and individual stakeholders interested in HCI as a professional activity. Gasen and Preece (1995) listed the main organizations that shape the face of HCI:[31]

1995 Gasen and Preece

What Shapes the Face of Human-Computer Interaction in Higher Education.

- University or School
- Departments
- Faculty
- Students or Professionals
- Business & Industry
- Government Agencies, National and International Organizations
- Professional Bodies
- Colleagues in the HCI Community

This list is indeed open to alien organizations and individuals. Curiously, the so called operators, users, or people whose work is actually supported or mediated by technology have not been included in the above list. Faculty, students, and professional can also be users, but in this list they are seen as potential developers. The motives for the omission appear straightforward, but they are complex. Users are not specialized, even slightly, in HCI and therefore it tends to be commonsense that they have nothing to contribute to its development. It seems reasonable that those who shape the face of a discipline are those who work in it. However, this then implies both that others are doing what those who work in technology are not and that those for whom they work have no influence on their organization.

The management of HCI's heterogeneity does not come without challenges. HCI and Informatics did not stagnate due to some of their prejudices being disseminated

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practices. His work in academic settings is particularly informative in the understanding of the political and cultural issues involved across professional activities (Bourdieu, 1988; Bourdieu and Passeron, 1990; Bourdieu and Wacquant, 1992)

[31] Their list is interesting to the argument presented in this thesis because it offers a spectrum of stakeholders that start at the academic setting and reaches the professional milieu.

across their communities. Design processes have been continually changing since their inception. Slowly and incrementally, foreign issues have been reactively and pro-actively incorporated across HCI practices, or discarded and avoided. But the process has not been smooth. The convoluted and sometimes idiosyncratic realm of the several disciplinary niches cuts through networks of status and power, making its long-term development a challenging task.

The historically established division of labor and power has a strong influence on professional relations. The presence of clearly delineated professional identities and roles across societies should not be condemned only because a myriad of gaps and contradictions can be identified among them. I stress once again, this does not invalidate the appropriateness of restricted professional foci. To be a specialist implies the mastery of a certain perspective. Its importance should not be overlooked, but must be understood critically. The attitude of the specialist may oscillate between two extremes. At one extreme, specialization becomes ineffective when professionals, empowered by the apparently self-sufficient status of their specialization, grant to themselves the right to rule out everybody else. It also becomes ineffective at the other extreme, when professionals grant to everybody else the responsibility for their practices.

However, professionals in both HCI and Informatics have neither the traditions, nor the frameworks to reflect on their profession from historically, culturally, ethically, and politically broad perspectives. Nevertheless, it is their responsibility to include such people and such issues into their daily practices, theories, and conducts. Unfortunately, the elitism found among professionals demands transformations that start at everyday tasks and reach issues of identity and social division of labor. Unfortunately, this elitism, which is unquestioned by most professionals in the field, is continuously reinforced when some professionals look down to peers in other fields. For example, elitism is nurtured so-called "human-centered" processes continue to ascribe decision power and originality only to designers, leaving nothing but passive roles "to lower" status "end" users.

In the full report entitled "New Directions in Human-Computer Interaction", Strong et al. (1994) commented on the ordering in which several HCI career paths were listed.[32] The comment dealt with the delicate issue of elitism present among HCI professionals. They listed the following professionals ranked in the following way:

1994 Gary T. Strong et al.

New Directions in Human-Computer Interaction (Strong et al., 1994, p 29)

- Researchers
- Researcher practitioners
- Systems and requirements analysts
- Ergonomists and human factors engineers
- "Converts" from computer disciplines
- "Soft" profession transfers
- Graphical design professionals

The apprehensive reader may note a certain elitism in the way that these [HCI] career path descriptions have been ordered. This was deliberate. There is a tendency for professionals within each of the categories to "look down" on professionals whose categories fall lower in the list. This is obviously not true for all professionals within any particular category. Nonetheless, this hierarchical order is reflected in many institutional behaviors, including hiring practices, salary determinations, influence within the corporation (although not necessarily within departments) and the likelihood of professional society participation. Professional societies tend to replicate this status hierarchy in their selection of members of conference committees, and at times in their selection of work for presentation.

Indeed, the historical inclusion or exclusion of people according to what they do or are has been discussed in HCI. A common categorization used to distinguish stakeholders is based on the different roles ascribed to academia and industry, between researchers and professionals, between theory and practice. But through periods of disciplinary reorganization the demarcation of what is theory and practice, what is the role of the designer and the user, and who owns a certain realm and who doesn't are usually reconsidered and renegotiated. In HCI the dichotomy of these categories

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[32] This comment has not been included the abridged version of the report (Strong, 1995).

has been increasingly blurred despite the strong academic/industrial orthodoxy, as I report in the following examples.

The cultural role of Informatics was not clear in academia during the mid twentieth century. Today some branches of Informatics have been socially recognized, but Informatics still does not have a clear role across society. Historically situating this point, I start with a comment from Louis Fein, uttered in 1959, to reinforce that the HCI community inherited some recurrent problems. Back in the fifties, Louis Fein discussed the role of the university in computers, data processing, and related fields. Commenting on the associated controversies, Fein listed four roles for computer scientists in academia: (a) to train professional scientists, (b) to train scholars, (c) to do exploratory research, and (d) to develop the new disciplines. Fein wrote:

1959 Louis Fein

The Role of the University in Computers, Data Processing, and Related Fields

(Fein, 1959, p 10)

The legitimate function of a university in any society has been subject of ancient and continuing controversy. The controversy has revolved around the questions loosely described as training vs. education, practical vs. theoretical subject matter; routine vs. non routine activities; scholarly vs. professional endeavor; and the various shades of green between.

In the same year, 1959, C. P. Snow wrote about the two cultures found in academia, in which literary intellectuals are at one pole and scientists are at the other (Snow, 1971, p 15). A third of a century after Fein's comment, Stuart Card said in an interview that computer science departments prefer hiring computer scientists and psychology departments prefer hiring psychologists despite the possible contribution or effectiveness of someone with a purely interdisciplinary background (Pitkow, 1996, p 30). In 1997, Andrew Sears, in a regular column on HCI education of the SIGCHI Bulletin, wrote that computer science departments are tied to tradition without an HCI advocate within its faculty. See Table 2.11 for longer quotes about the difficulties interdisciplinary work. They illustrate the challenges yet to be faced

1959 C. P. Snow *The Two Cultures and the Scientific Revolution* (Snow, 1971, p 15)

Literary intellectuals at one pole – at the other scientists, and as the most representative, the physical scientists. Between the two a gulf of mutual incomprehension [...] They have a curious distorted image of each other. Their attitudes are so different that, even on the level of emotion, they can't find much common ground. Non-scientists tend to think of scientists as brash and boastful. [...] On the other hand, the scientists believe that the literary intellectuals are totally lacking in foresight, peculiarly unconcerned with their broader men, in a deep sense anti-intellectual, anxious to restrict both art and thought to the existential moment. And so on

1996 Stuart Card being interviewed by James E. Pitkow (Pitkow, 1996, p 30)

The Evolution of the Student Experience: Interview with James Foley and Stuart Card

While interdisciplinary training gives a student the best shot of solving novel problems, which often consist of merging ideas of two conventional fields, most academic departments take the attitude for hiring that you should be good at whatever they are first, then you can do this HCI stuff. So computer science departments want to hire people who are computer scientists first and HCI people second. Psychology departments want to hire people who are psychologists first and HCI people second. You've got to know the secret handshake. So my advice for a student aiming for an academic career is to shape his or her education to fit into the shape of a conventional department and specialize in HCI from there, rather than doing a purely interdisciplinary program.

1997 Andrew Sears *HCI Education: Where it is headed?* (Sears, 1997, p 8)

If the fact that HCI is not part of the traditional definition of computer science, psychology, or whatever other discipline the department emphasizes, causes it to be seen as less rigorous or less important, HCI will not expand beyond being an elective [...] If there isn't an advocate for HCI, or if the department is too tied to tradition, HCI cannot thrive in a single-discipline department.

1997 Gail McLaughlin *HCI Education and CHI 97* (Sears and Williams, 1997, p 9)

Most people don't have a clue of what HCI is; project leaders see no difference between a designer and a developer; there is a perception that talking to the end users is a waste of time; there isn't enough time to do the usability testing; 'user friendly' means having a graphic artist make the interface pretty after its developed; people in the corporate world expect that they throw a bunch of people together on a team and work effectively[...] Corporations don't recognize the value of the knowledge and skills of the HCI graduate. Universities don't teach students basic skills necessary to be effective in the corporate world.

Table 2.11: **Disciplinary barriers between HCI and Informatics**

within HCI and informatics.[33]

A theoretical scaffold intended to support design should foster an open attitude towards the situation in which the professional intervenes. During HCI's consolidation years, most research and development was carried out either in isolated academic or in industrial laboratories. This was in accordance with the established non-intersecting roles ascribed to researchers and to professionals. Even the computing artifact was isolated in centers of data processing.

When the ecology of Informatics consolidated, the communities structured a process composed of the following sub-division of activities: (i) researchers prescribed solutions (i.e. design), (ii) professionals implemented them (i.e. deploy), and (iii) users employed them. Until today, this specialization chain has been effective as long as the produced goods fulfill the expectations and the actual needs of the various stakeholders. The fast-paced development of Informatics nurtured the maintenance of this linear professional pattern, giving stability to this labor division and work flow. This linear distribution of work, and its scheduling across time, formed the scaffold that still sustains design as a cultural process. Not only in HCI and informatics, but also in engineering and in industrial design, the activity of design is usually narrowly conceived and practiced.

A related example is the categorical demarcation of theory and practice, and the underlying assumption that the latter follows the former.[34] Researcher and professional, for example, are roles that have been in consonance with the distinct cultural roles established for the institutions they usually are part of, academy and industry.[35]

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[33] Informatics broadly understood spans across Snow's academic gulf of incomprehension. Computer science, for example, is heavily structured around programming *languages*, *information* management, and more recently *communication networks*. Although it is still a product-centered "science", the community itself is becoming increasingly aware that the discipline should also be humanly and ethically driven.

[34] A related example is the definition of engineering as "useful arts" or "applied sciences", found across the nineteenth and the twentieth centuries.

[35] The terms vary, however. In sociology, for example, criticisms are founded on the dichotomy found between theory and research, (Bourdieu and Wacquant, 1992, p 34), in which the latter follows

These categories do not come from just anywhere. They are in accordance with the work flow delimited by networks of specialization established across our societies. That does not mean that these networks are just or democratic.

Several authors have attempted to foster inter-disciplinary practices across and beyond HCI. Some have proposed revisions of HCI's roles and their boundaries. A form of revision is to bridge conceptual categories that traditionally tie stakeholders to specific niches and to particular forms of organization. An interpenetrating revision of professional categories implies a renewal of the whole professional organization, because it necessarily impacts practices and identities across the whole field.

The responsibility of a professional goes well beyond his or her specialized niche. Design interventions within HCI and Informatics involve people, machines and their joint activities. However, as I have discussed before, Informatics' constellation of interests have been increasingly focused on product, leaving human and activity related issues on their outskirts. During the development of HCI, which evolved on the outskirts of Informatics, the distinction between researcher and professional became dysfunctional. It also became evident that HCI necessarily involves fieldwork, compromise among stakeholders, and reflection on the long term consequences of its interventions.[36]

In the sequel, I present three examples that increasingly foster the interdependence of multiple niches across the HCI field. In 1989, Marilyn Mantei bridged the categories of the *researcher* and the *professional* by softening their sharply defined roles with the introduction of two intermediary roles: the *professionally oriented researcher* and the *research oriented professional* (Mantei, 1989, p 17).

Intervention on people's attitudes is not instantaneous. It demands negotiation and flexibility. In Mantei's description of HCI's roles depicted in Figure 2.12 it is

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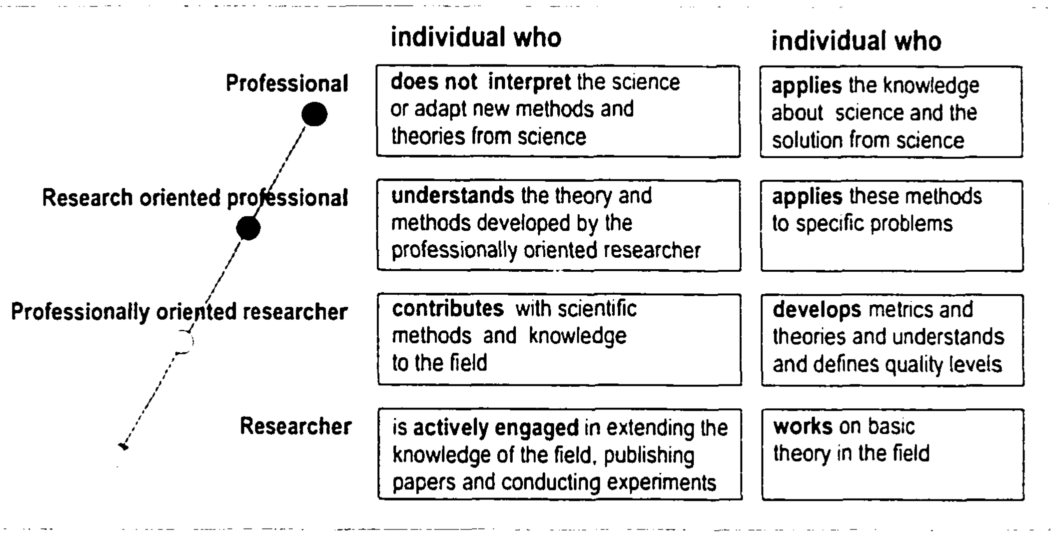
the former.

[36] Suchman's work on human-machine communication represents a clear criticism of the sequential relation between planning and action (Suchman, 1987). ***** (Shön, 1983) criticized design current practices and proposed the reflective practitioner as a professional that reflects in action, breaking the dichotomy between theory and practice.**



	individual who	individual who
Professional	**does not interpret** the science or adapt new methods and theories from science	**applies** the knowledge about science and the solution from science
Research oriented professional	**understands** the theory and methods developed by the professionally oriented researcher	**applies** these methods to specific problems
Professionally oriented researcher	**contributes** with scientific methods and knowledge to the field	**develops** metrics and theories and understands and defines quality levels
Researcher	**is actively engaged** in extending the knowledge of the field, publishing papers and conducting experiments	**works** on basic theory in the field

Figure 2.12: **Mantei's roles between the researcher and the professional.** Based on (Mantei, 1989, p 17)

possible to identify the flow of communication and power between academia and other social segments. The traditional flow that reifies the university as the origin of knowledge and commerce and industry as the recipients of knowledge can be easily recognized. Researchers are *actively engaged* and *work*. Professionals *do not interpret* and only *apply* what researchers do.[37] When Mantei blurred the established social division of labor by suggesting new intermediate roles, she also maintained the historically consolidated sequential pattern of communication and power crystalized across the academic and industrial cultures. Mantei wrote:

> 1989 Marilyn Mantei *An HCI Continuing Education Curriculum* (Mantei, 1989, p 4)
>
> The best and brightest people are not people working on product development, but researchers. [...] Although the industrial world will be the eventual recipient of the products of the recommended curriculum, their concern is too pragmatic and focused on solving day-to-day problems to give them the skills (or time) to think about the foundational knowledge of HCI.

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[37] A related example is the distinction between the role of designer and the role of the user, separated as if the former were the source of goods, and the latter the passive recipient.

In today's context, Mantei's position may seem orthodox and conservative, but framed in the nineteen eighties, and considering what she was trying to bridge, it may be interpreted as progressive.[38] The two other models that increasingly blend professional roles are by Suchman and Trigg, for HCI, and by Braa, for Information Systems, which I address in the sequel.

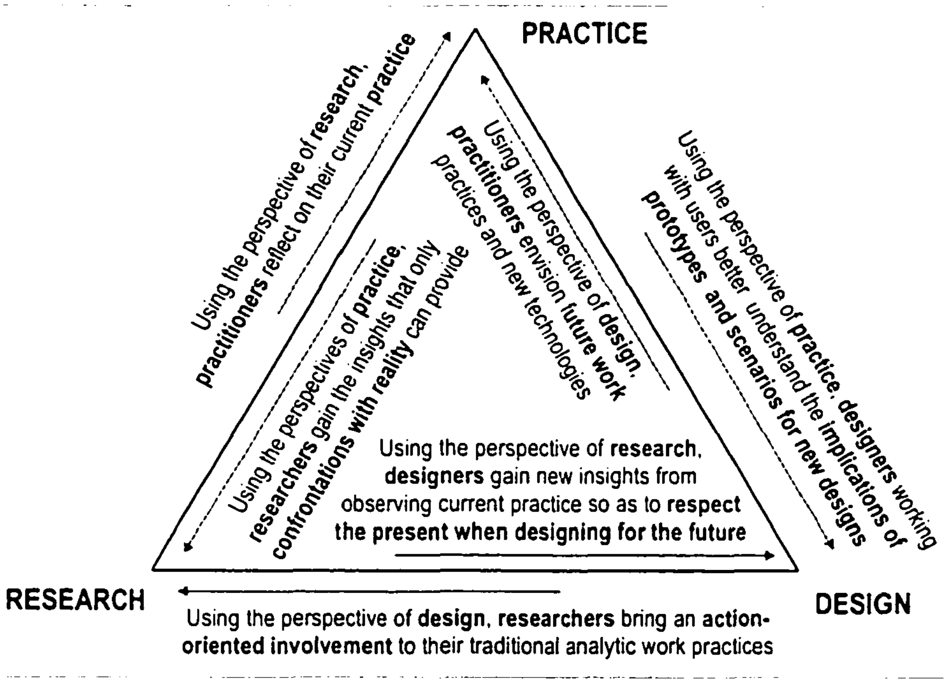

Figure 2.13: **Suchman's disciplinary bridges among research, design, and practice** (Suchman and Trigg, 1991, redrawn)

In 1991 Suchman and Trigg explored the advantages of team work using video as a medium for a reflective practice of design. In their paper they discussed the relations among activities of research, design, and practice using a triangular diagram similar to the one depicted in Figure 2.13. Using the sides of a triangle, Suchman and Trigg discussed several perspectives in technology development (Suchman and Trigg, 1991, p. 86). Suchman and Trigg deliberately avoided the terms researchers, designers, and practitioners in order to go beyond the established "division of labor between

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[38] See also Mantei-Tremaine (1998) for a recent appraisal of her role in a computer science department as a psychologist.

participants in the systems development process" (Suchman and Trigg, 1991, p 85). This model indeed fosters a revision of the professional links into a non-sequential, and consequently less hierarchical, division of labor.

In 1995 Braa defended a model in which several methodologies are plotted in accordance to activities related to information systems design. The model uses a triangular space usually employed to represent proportions among three elements. The vertices of a triangle correspond to abstract pure activities that emphasize only prediction (science), only understanding (use), or only change (intervention). See Figure 2.14(a). Different methodologies are plotted in accordance with their main tendencies. Figure 2.14(b) illustrates the approximate domains of different approaches such as field experiment, hard case, soft case, action research, and action case as discussed in Braa (1995).[39]

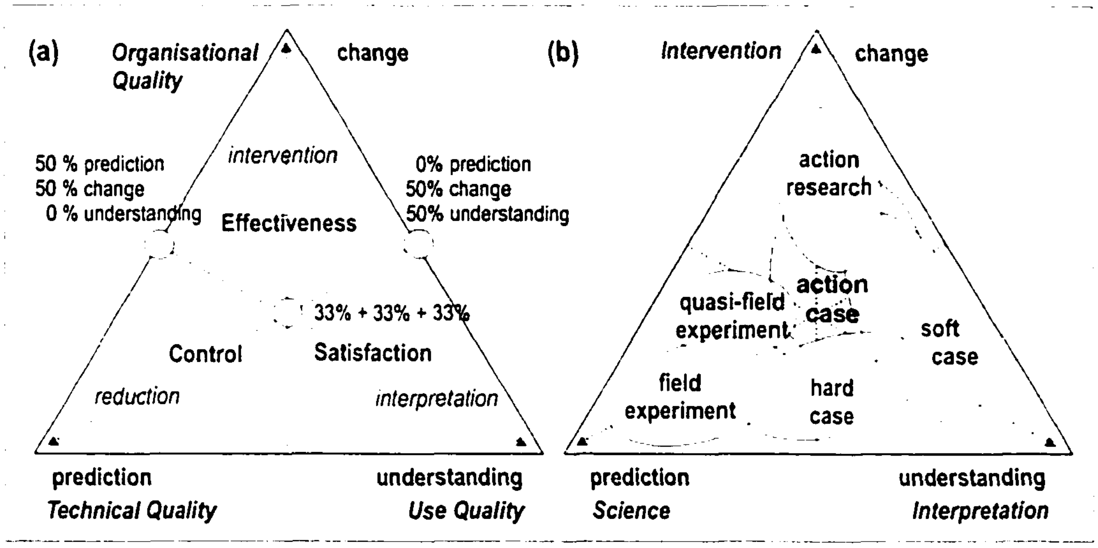

Figure 2.14: **Braa's space of information systems** (Braa, 1995, redrawn)

The cultural ecology of HCI involves many other professionals than the researcher, the designer, the practitioner, and the user. Technological intervention processes include different stakeholders at different moments. These three examples all illustrate

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[39] For a broad introduction to case studies, see Yin (1994). Linn and Clancy, for example, have explored case studies methodologies in Software Engineering (Linn and Clancy, 1992).

perspectives that call for an enrichment of the professional realm traditionally maintained in Informatics and in HCI. They illustrate how distinct categories are bonded, enabling new forms of professional interaction, communication and organization than the traditional linear chain.

2.6.2 HCI 3D Conceptual Framework

Up to this point, I have described HCI and Informatics with the aid of a technical and a human dimension. The just mentioned models and references add at least a third dimension to HCI and Informatics.[10] The third column of Table 2.10 labeled "interaction" lists elements such as task, use, organization, communication, skills, norms, service, activities, business, design, change, and ethics.

Figure 2.15 depicts an extension of the 2-dimensional conceptual space with the aid of an "interactive dimension" in a third dimension. Scales developed in Theory of Activity to describe mediated action, and developed in language studies to describe languages are possible candidates to exemplify the use of a third dimension to characterize the nature of HCI.[11] HCI areas tend to focus on longer activities as they include more people and more artifacts.

In Cultural and Historical Activity Theory[12], activities are mediated by language or by tools. I have used a scale to organize the coordinates of Figure 2.15 initially developed in Activity Theory by Aleksei Nikolaevich Leont'ev. He characterized activities in general as encompassing three interdependent strata described as oper-

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[10] The use of three dimensions to correlate and visualize data is not new in related areas. In cognitive science, for example, Paul M. Churchland has used 3D coordinate spaces to represent sensory data, which he called initially a "color sensation space" (Churchland, 1997, 148-149), and more recently sensory representation through "vector coding" (Churchland, 1996, p 21-34). However, I have not seen similar models exploring disciplinary relations. Even if they exist, the literature that has been discussing the nature of HCI and Informatics has not been using this kind of diagram to explore disciplinary relations.

[11] What is important is not exactly which dimensions are used to describe a disciplinary field, but the awareness that "a model" is only a projection of a multidimensional disciplinary system.

[12] See Appendix D for references of Activity Theory, including its relations with HCI.

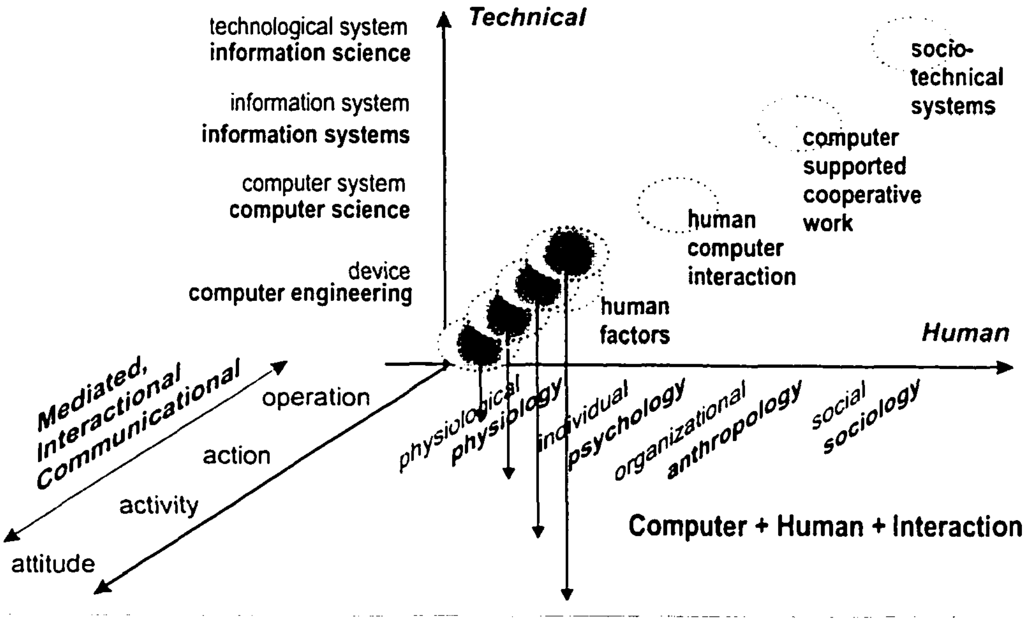

Figure 2.15: **Foci of HCI's main disciplinary niches of specialization**

ations, actions, and activities (Leont'ev, 1978, pp 62-69). Operations have a smaller scope than actions, which have a smaller scope than activities.

In HCI design, Raeithel and Velichkovsky (1996) discussed the adequacy of methodologies associated with Leont'ev's "levels" of activities between designers and users in relation to the processes of observation, experimentation, design, and evaluation. See Figure 2.16. The different approaches listed by them complement well the analysis that I have been doing of correlating disciplines with subject matters.

The diagram in Figure 2.15 is expressive enough to represent narrower and broader niches than the ones usually associated with HCI. Repetitive strain injury, for a broader example, goes from the sensorimotor system, closer to the "operations" strata, to a person's whole life, having intricate organizational and political issues associated with them. The focus of such an example may be smaller, but the boundaries engulf HCI traditional niches.

Not everybody is comfortable with three dimensional spaces projected on two dimensional surfaces to depict disciplinary relations. Considering the effectiveness of two dimensional diagrams, and on the historical continuity of the model presented in

Raeithel 1996		Examples of adequate methodology for:	
Process level	**Type of development**	**Observation and experiment**	**Design and evaluation**
Activity	**Historical**	Ethnographic Field Research	Evolutionary
	Sociocultural	Naturalistic observation	Object oriented
	Micro social	Field experiment	Participative
Action	**Ontogenetic**	Formative experiment	Stage genetical
	Deliberate	Aims and results assessment	Task oriented
	Habitual	Co-construction of views	Metaphors and prototypes
Operation	**Micro-genetic**	Joint attention experiment	Tool oriented
	Self-organizing	Video analysis	Convivial tools, soft machines
	Conditioned	Factorial experiment	Ergonomic

Figure 2.16: **Raeithel's levels of activity as in activity theory** (See Raeithel and Velichkovsky, 1996, p 228, redrawn).

the SIGCHI curriculum. I sketched an alternative model in which some of the issues that I have discussed until now are graphically represented. I remark that like the SIGCHI model, its planar organization limits the representation of some disciplinary relations easily depicted in a 3D chart.

Figure 2.17 illustrates a pictorial model for the nature of HCI considering the human (left), the technical (right), and the interactive (center) dimensions. The scales go from bottom to top. I have moved "genres" and languages to the center column, and have changed the terminology and the level of detail used to describe the human components. The three items within contextual issues have also been centered. To complement design issues, I have also added on the top of the diagram a process denoting policy making processes in informatics.

2.6.3 Examples: Disciplinary Trajectories across History

In this section, I illustrate the use of the proposed 3D diagram for the nature of HCI by visualizing some historical HCI and Informatics disciplinary trajectories described in the literature. In Table 2.12, I quote some authors who commented on HCI's historical development.

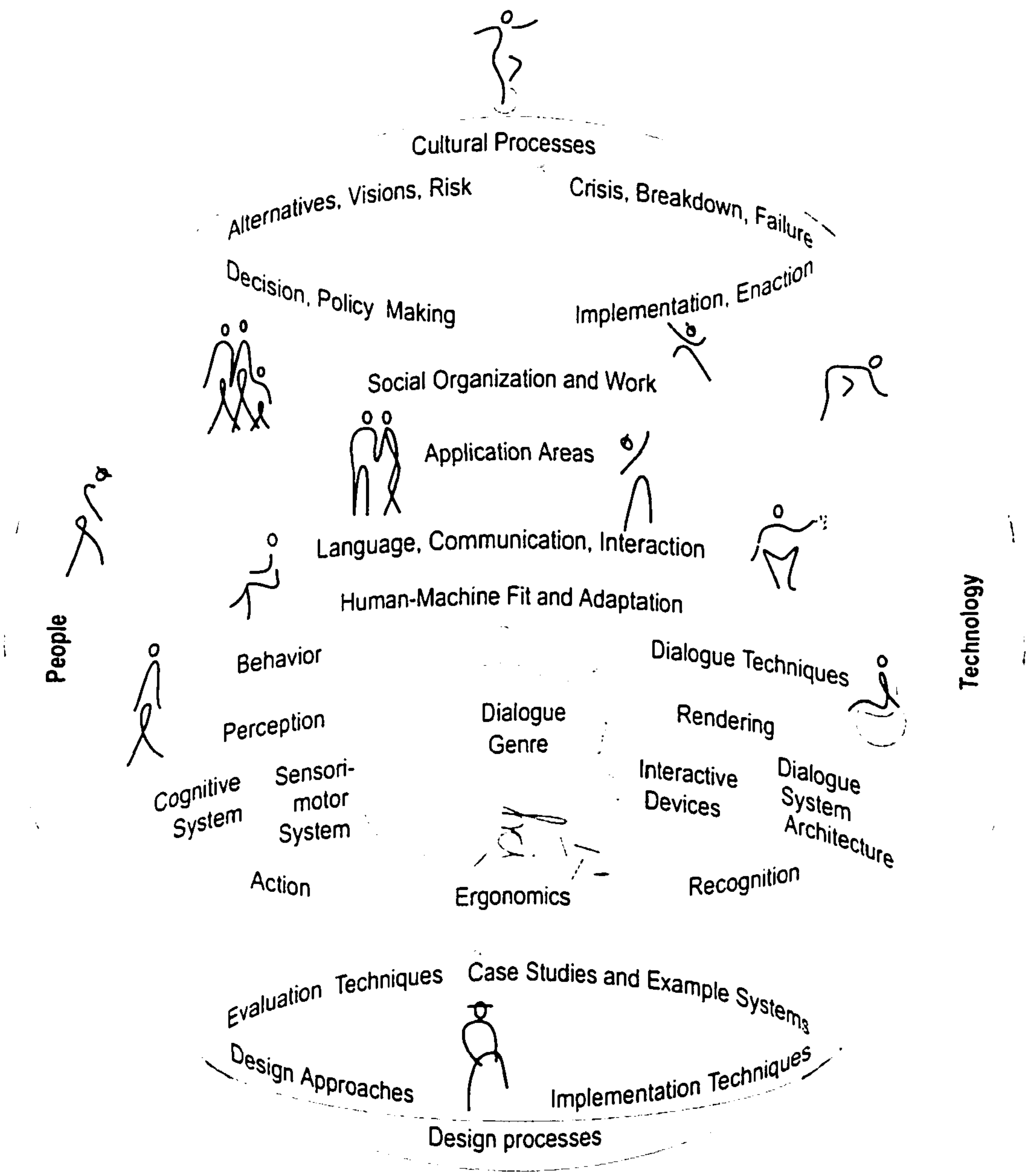

Figure 2.17: **The nature of Human-Computer Interaction:** A 2D Projection of HCI's Conceptual Space. This space can be extended with other information. In Chapter 4, I further extend this diagram with process models from software engineering to illustrate this capability.

1984 Allen Newell and Stuart K. Card

The Prospects for Psychological Science in Human Computer Interaction

(Newell and Card, 1985, p 235)

To all intents and purposes, then, the psychology of human-computer interaction is the psychology of interaction with the canonical interface.[...] It sharply distinguishes the psychology of human-computer interaction from general human factors.

1998 Daniel Boyarski

Designing Design Education (Boyarski, 1998, p 9)

Human-centered Attitude [...] takes into account the human factors of cognition, behavior, even social and cultural influences. [...]

This human-centered approach is undergoing an evolution from user-centered design (considering the audience) in the 80s, to participatory design (involving the audience) in the 90s, to design partnerships (involving the audience *and* client) in the first decade of the new century.

1999 Eamonn O'Neill, Hilary Johnson and Peter Johnson

Interacting in the Large: Developing a Framework for Integrating Models in HCI

(O'Neill et al., 1999)

Modelling in early HCI concentrated largely on the individual user of a computer system. HCI has expanded its range of concerns to include the social, organizational, and environmental setting of interaction between possibly more than one user and more than one computer. The range of models used in HCI has correspondingly increased.

1999 James D. Hollan

Entry on *Human-Computer Interaction* (Wilson and Keil, 1999)

Overall, as Grudin (1993) has pointed out, we can view the development of HCI as a movement from early concerns with low-level computer issues, to a focus on people's individual tasks and how better to support them, to current concerns with supporting collaboration and sharing of information within organizations.

1999 Lars Oestreicher

Six Golden Rules to Shake the Student's Mind (Oestreicher, 1999)

One problem with HCI is the narrow focussing on the computer, and it was also stated [by the workshop participants] that the HCI needs to free itself of the burden of the computer. Thus there will be a transfer from teaching Human-Computer Interaction (HCI) to Human-Machine Interaction or even in the most general perspective Human-Artefact Interaction.

Table 2.12: **HCI's foci trajectories across history**

In particular, I exemplify the use of the 3D diagram to illustrate the historical trajectories developed by Jonathan Grudin and other authors. Jonathan Grudin published a series of articles addressing the historical development of CSCW, and of the concept of interface in different settings and cultures.[13] Liam Bannon's publications also address several issues in HCI's historical development, describing his pilgrimage from cognitive sciences to cooperative design, from human-factors to human-actors, from HCI and CMC to CSCW, and from storage to active remembering in organizations.[14]

As a reference point I start with Newell and Card's delimitation of HCI carried out in the early 1980s. Newell and Card used the limited correlated variability across interactive equipment to propose a canonical interface, simplifying the analysis of human-computer interaction with the imposition of similar constraints on different interfaces (Newell and Card, 1985, p 235). For Newell and Card capability of interactive equipment increases over the years, but slowly enough to be factored out in a "hard science" of HCI. According to them, this sharply distinguished HCI from the "immensely more variable open environment" of general Human Factors.[15]

Newell and Card actually wrote:

1984 Allen Newell and Stuart K. Card
The Prospects for Psychological Science in Human Computer Interaction
(Newell and Card, 1985, p 235)
The canonical interface[:] Most human-computer interaction takes place by means of only a few devices that are in mass use. The features of the members of each device class tend to be similar (e.g. all typewriter terminals tend to have speeds in a similar range). As years go by, the number of users with various types of equipment slowly changes.

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[13] See Grudin (1990, 1991b,c,a, 1993, 1994b,a, 1996, 1998) and Grudin and Poltrock (1995).

[14] See Bannon (1990, 1991, 1992b), Bannon and Shapiro (1994), Bannon and Kuutti (1996), and Bannon (1997).

[15] The relative order used by Newell and Card to classify HCI and human factors is the inverse of the one depicted in the human dimension used here. This reinforces my remark that such scales are only conceptual and do not demarcate boundaries, but indicate main trends.

> This limited and correlated variability in equipment simplifies the analysis of human-computer interaction by imposing similar constraints on different interfaces. [...] To all intents and purposes, then, the psychology of human-computer interaction is the psychology of interaction with the canonical interface. This is a remarkable situation. It sharply distinguishes the psychology of human-computer interaction from general human factors, which must deal with an immensely more variable operating environment, and hence has a much harder task. The canonical interface is the feature, if any, that might make possible a separate discipline of human-computer interaction.

By comparison, while Newell and Card considered these changes to be slow enough to be factored out, they are the actual focus of Grudin's analysis. Grudin described the history of interface design as a continuous drift starting at the inner workings of hardware issues and reaching the work setting. Grudin's description of the focus of interface design is accordance with the traditional description of informatics, in which its main focus has drifted from narrower to broader issues. Grudin characterized this trajectory in five periods:

> 1990 Jonathan Grudin
>
> *The Computer Reaches Out: The historical continuity of interface design*
>
> (Grudin, 1990, p 262)
>
> [1] Initially, the user interface was located at the hardware itself – most users were engineers working directly with the hardware.
>
> [2] The focus than moved to the programming task – higher-level programming languages and progressively freed the user from the need of being familiar with the hardware.
>
> [3] Next, with the widespread appearance of interactive systems and non-programming "end-users," the user interface shifted to the display and keyboard, with early attention to perceptual and motor issues.
>
> [4] Recent years have seen increasing research focus on users' "conversational" dialogues with systems and applications, involving deep cognitive issues underlying the learning and use of systems: the user interface is extending past the eye and fingers, into the mind.

[5] Finally, with the advent of "groupware" and systems to support organizations, we are beginning to see the focus of user interface design to extend out into the social and work environment, reaching even further from its origin at the heart of the computer.

In other works Grudin discussed CSCW's history from 1965 to 1985 (Grudin, 1994a,b, 1998). In these papers Grudin presented the scope of Informatics through concentric circles spanning the individual and the organization, passing through the small group. A closer look, however, shows that the years associated with each circle do not increase linearly. In Figure 2.18(b), I list Grudin's collected information. I took the liberty to add two periods, one before the 1960s (1945 –) and one after the 1990s.

Apparently, the trajectory described by Grudin of CSCW's history follows the same expansive pattern. However, once the two trajectories are plotted on the three dimensional diagram, the curve that CSCW draws does not grow monotonically. See Figure 2.18(a) for the foci of interface design according to Grudin.

Figure 2.19 exemplifies how the 3D diagram introduced earlier can be used to visualize the historical trajectory of interface design and of CSCW as told by Grudin and by other authors.[16] In Grudin's original circular diagram, mainframes, systems, and the organization were the foci in 1965. The respective disciplinary focus was on data processing, information technology, and the management of information systems. In 1975 Informatics drifted to minicomputers, workflow, and specific projects, with a respective shift to software engineering and office automation. Later on, the foci shrunk to the individual computer and product development, but expanded towards HCI and human factors as approaches. With networks of PC's, the scope increased again, and CSCW emerged as a field. Chronologically, this goes from the broader environment of the organization, passes through the local issues of the individual user, and goes back to the slightly broader issues of small groups. This resembles the disciplinary funnelling of Informatics discussed in Chapter 1. During the nineties, HCI has expanded towards uncharted and earlier avoided or prescinded realms.

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[16] It is interesting to see Figure 2.19 in the light of Figure 2.9, in which human and technical dimensions are correlated in two pictures. I remark that Figure 2.19 only illustrates conceptual foci.

(a) Interface	Design as	Principal Users	Interface specialist discipline
1950s	Hardware	Engineers, programmers	Electrical Engineering
1960-1970s	Software	Programmers	Computer Science
1970s-1980s	Terminal	"End users"	Human factors, cognitive psychology, and graphic design
1980s-	Dialogue	"End users"	Cognitive psychology and cognitive science (and dramatic arts?)
1990s-	Work setting	Groups of users	Social psychology, anthropology, and organizational studies.

(b) CSCW's	Scope	Development	Product	Example	Area/Discipline
1945	*Group*	*Research and Military labs*	*Calculating Machines*	*Mainframe Robots*	*Cybernetics Automation*
1965	Organization	Internal	Systems	Mainframe	Data Processing Management IS, IT
1975	Project	Contract and Internal	GDSS / Workflow	Minicomputers Networks	Software Engineering Office Automation
1980	Individual	Product	Applications	Personal Computer (PC)	Human Factors CHI
1985	Small Group	Product and Telecom.	Computer-Mediated Com.	Networked PC 's Workstations	Computer Supported Cooperative Work
1990	*Large groups*	*Product and Service*	*E-service*	*Networked PC 's,* *mobile devices*	*Informatics?* *IT?*

Figure 2.18: **CSCW and interface design history:** (a) based on Grudin (1990, p 265) (b) based on Grudin (1994a, 1998)

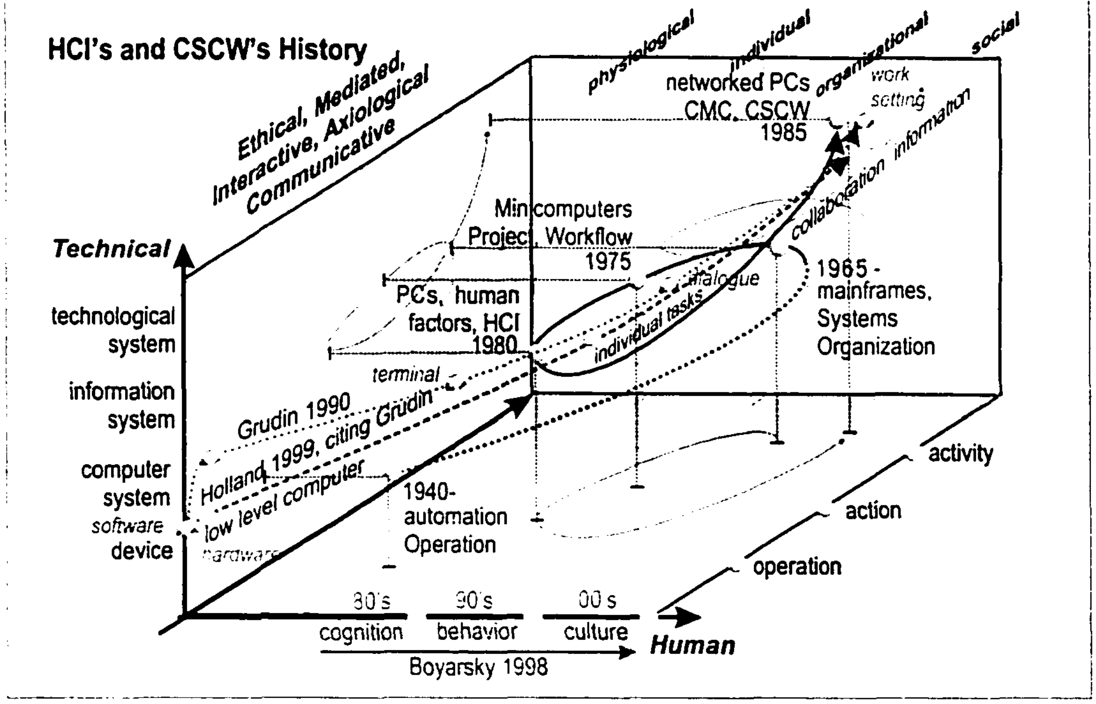

Figure 2.19: **Historical trajectories of CSCW and interface design**

I have also depicted in Figure 2.19 the trajectory described by James D. Holland in reference to Jonathan Grudin (1993)'s analysis of the evolution of the concept of interface and the trajectory described by O'Neill et al. (1999) who mentioned the increasing range of models used in HCI.

2.7 Summary and Final Remarks 2

Educators have been discussing the importance of certain trends and the appropriateness of research directions since the inception of informatics. Any research, development, or reflection that intervenes across the field as a whole, within a particular specialization or area, or even in a single individual at a certain moment, is either transforming or sustaining human values associated with them. Across informatics and HCI, it is possible to find many publications addressing disciplinary relations. Several of these endeavors explore specific relations among two or three disciplines. A small number of publications have addressed design as communication, bringing to informatics reflections developed in linguistics, hermeneutics, semiotics, cultural and historical psychology, and language studies, among others. Among the many available options as foundations for a communicative facet of Informatics and HCI, this thesis proposes the related work of Charles Sanders Peirce, known as the forerunner of both Semiotics and Pragmatism.

Disciplinary boundaries are necessary for the consolidation of disciplinary niches, which include the sustainable development of communities, practices, theories, attitudes, identities, policies, and so on. What is appropriate or not, on what tenets it is centered, where one discipline ends and another begins, whether two or more disciplines intersect or whether there is a gap between, what should be given priority in a subject, and when should a certain subject be given priority, together of many other issues, have been the motivation not only of arguments and quarrels among different currents of thought and practice, but also discussions of the advantages and strengths of interdisciplinary endeavors, despite the associated challenges. The differences in perspectives of where a field starts or ends, towards or from where it should expand or retract, or in consonance or contradiction with whose interests or what vary considerably. These limits vary across people, across schools, across countries, across history. The professional challenge is to achieve unity among this diversity. I refer to the diversity of emphases that structure a certain field its constellation of interests.

This chapter focuses on disciplinary relations and disciplinary diversity across the historical development of the field of Human-Computer Interaction. The field of Human-Computer Interaction has been characterized many times as a field spanning boundaries due to the large number of disciplines that have contributed to it. The communities in HCI have slowly recognized the importance of disciplinary diversity across its foundations. In this sense, HCI communities are a phase ahead of traditional fields in informatics, which have only recently faced the challenge of a diversity that has since been forgotten.

Nevertheless, HCI has not been immune to the historical disciplinary forces that constitute its disciplinary grounds, such as the cognitive and the computer sciences. This influence is visible in the main models that discuss HCI's nature, with a clear bias in favor of dyadic frameworks that emphasize the single user of a single computer. Using a disciplinary chart, I propose a conceptual model of HCI's constellation of interests that also emphasizes other tendencies present in its cultural ecology.

A three dimensional model is progressively built with the inclusion of additional facets respectively linked to technology, people, and their interactions, which is in consonance with Peirce's systematic philosophy. I have four main goals with this representation or model. Firstly, I want to compare different areas in a single diagram. Secondly, by showing the simultaneous presence of more than one perspective on a single discipline, I would like to facilitate the interdisciplinary work among Informatics' disciplines and with other disciplines. Thirdly, I would like a method that could be used with other or more dimensions than the ones discussed here. And fourthly, I intend to facilitate the characterization of computer semiotics within Informatics, in order to delimit the scope of the second part of this thesis.

In this conceptual framework, visualized as a multi-dimensional disciplinary chart, distinct constellations of interest can be compared in relation to established academic fields. In the charting of HCI and informatics. I have used three basic dimensions. which encompass the organizations of (i) artifacts. (ii) humans. and (iii) interactions. I have chosen these three dimensions in accordance with my objectives of describing the cultural ecology of HCI. the role of the humanities in it. and in particular. the role of communication in close resonance with Peirce's work.

These dimensions correspond roughly to the foci of disciplines such as (i) computer engineering. computer science. and information systems in a first group; (ii) physiology. psychology. anthropology. and sociology in a second group; and (iii) linguistics. language studies. and media and cultural studies in a third group. A focus on computer architecture would be narrower than a focus on net-centric computing. but a focus on engineering telecommunications. despite its usual broader physical scope. would be even narrower because telecommunications is only a part of a network.

A close analysis of each of these dimensions or disciplines shows that they are not as isolated as they first seem. For example. in the history of informatics many disciplinary joint works can be identified. such as. automation and cybernetics (control systems). engineering and management (management systems). automation and linguistics (automatic translation). mathematics and linguistics (either programming languages or theory of computing). artificial intelligence and psychology (cognitive sciences). etc.

Nevertheless. I should remark that I have limited the scope of this chapter to the charting of disciplinary relations. exclusively. I do not discuss the value of. the motivations for. or the effectiveness of such disciplinary relations. Despite their importance. I have limited myself to chart such barriers and bridges within a multifaceted model. Within this delimitation. I have left out many important issues discussed in the literature. such as the difficulties. advantages. and political consequences of these disciplinary relations.

The conceptual framework and its visualization are enough expressive to depict the history of HCI at a higher level of detail than it is usually described. showing that although it continues to expand. the expansion is not monotonic and present phases of retraction.

Technology has a purpose. Therefore, in relation to Peirce's work, in which interactions and representation are important facets, technology would necessarily link phenomena to *ends*, reaching at least the level of the Normative Sciences. HCI, would go beyond Peirce's philosophy because it presupposes Psychology, which presupposes it.

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Chapter 3

Design Processes

> ... perhaps my first sculpture where the space
> and the form are completely dependent on and inseparable from each other.
> I had reached the stage where I wanted my sculpture to be truly three dimensional.
> In my earliest use of holes in sculpture, the holes where features in themselves.
> Now the space and the form are so naturally fused that they are one.
> Henry Moore, 1951 [1]

> Redemoinho: o senhor sabe – a briga de ventos.
> O quando um esbarra com outro e se enrolam, o doido espetáculo. [...]
> O que pensei: *o diabo, na rua, no meio do redemunho ...*
>
> Jõao Guimararães Rosa, 1956 [2]

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[1] Henry Moore's comment about his sculpture entitled *Reclining Figure*. Festival, 1951, Bronze (Hedgecoe, 1998, p 116)

[2] Jõao Guimararães Rosa, 1956. *Grande Sertão: Veredas*, Nova Fronteira, p 213.

In English:
Swirling eddies - you know, winds fighting.
When one meets another and they whirl together, it is a crazy sight [...]
The devil in the street, in the middle of the whirlwind.
Jõao Gumararães Rosa, 1963.
The Devil to Pay in the Backlands.
p 205.

The majority of design process models prescribe sequences of activities in close consonance with already established professional specialization and work flow. This is not a problem per se, but across periods of professional reorganization, as the one Informatics is passing through at the beginning of the millennium, is necessary to review both design processes as well as the established disciplinary order in order to prepare the continuation and the development of Informatics as a whole.

Unconsciously, however, design process models have been reactive, not pro-active. There is a continuation of the tunnelling tendencies of the past. For example, advocates of user-centered design fall easily into hypocrisy, calling for human-oriented perspectives as long as the control of the process remains in his or her hands. An exception, among many already mentioned, is the community of participatory design which has been discussing the full inclusion of stakeholders in design processes since the 1960s (Trigg and Clement, 1999).

Informatics and its design processes, while narrowly understood and practiced, is usually limited to a product-centered short-term perspective. I have limited the discussion about design processes in this thesis at a point midway between the individual and the social levels, the isolated artifact and the interconnected system, the short-term and the long term activities, focusing mostly on factors usually discussed at the organizational level.[3]

The conceptual model of HCI introduced in the preceding chapter is rather static. It enables a characterization of the disciplinary heterogeneity of HCI and Informatics as multiple constellations of interest. In this chapter I add elements associated with process to the multidimensional conceptual model, turning it into a conceptual process model.

The descriptive characteristic of design process models and methodologies usu-

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[3] I remark that this restriction does not decrease the importance either of narrower or broader foci. I decided to leave the comprehensive consideration of the social, ethical, and historical issues involved in design to my future work. Therefore, the work presented here is only as a start, as a rough sketch of my full interests.

ally prescribe professional action, leaving almost no space for professional pro-active engagement. They are meant to be instruments to scaffold activities, not to straight-jacket stakeholders. I understand that design process models should enable the stakeholders themselves to decide how to proceed. The process model of design proposed here does not determine the future of HCI's interventions. It only roughly delineates or restricts their possible trajectories within a multidimensional space. As it is discussed in this thesis, the framework emphasizes the description of a design space, facilitating the visualization of narrower and broader design processes. It does not prescribe best or worst trajectories.

The examples in the next section further illustrate the interdependence of cultural niches present in HCI and Informatics, as already shown in the two first chapters. This is intended to illustrate the thesis with models that have attempted to go beyond the narrow scope of product centered perspectives and isolated disciplines. To address the interaction between disciplines, I proceed now with one form of interaction, which is communication.

3.1 Models of Communication

The development of models of communication, interaction, and computation vary across history. These models went from the complex to the almost linear topology across the early nineteenth century, and from the almost linear to the complex in its latter half. The most diffused model of communication is the duct model, which is linear and unidirectional.

Informatics and HCI has always had a strong relationship with linguistics and mathematics. Indeed, this bond has always been present throughout the history of Informatics. There is no novelty in the link per se. The novelty is in the depth of the link. It is enough to ask what would be of the field of Informatics if there were no syntax, no grammar, no compilers and interpreters, no write or read instructions, no programming and formal languages, no transmitters and receivers, no fluxograms and other graphic formalisms, no channels, no communication networks, no codes, no protocols, and so on.

However, this link with "communications", as it is, is not sufficient. It is also necessary that it includes broader world views. People in Informatics and HCI have been very selective in the choice of semiotic theories and models that they have incorporated and further developed across their practices. At the end of Chapter 2, in Figure 4.1, I illustrated how narrow the foci of Informatics have been in relation to language scales and hierarchies. In this section I further elaborate this point, using models of communication and interaction instead of using language hierarchies.

A comprehensive appraisal of communication models is important to HCI in the sense that it may facilitate a broader and more critical understanding of the fundamental concepts of information and interaction.[1] To engage in communication implies to act on a common endeavor, be in agreement or disagreement, in consonance or in contradiction. Models of communicative processes, as any other models, are abstractions. As abstractions they vary in function of what they reject or include, of what they model or not. With a brief comparison of different models I intend to illustrate the great variability across models with respect to the degree in which either commonality or alterity is assumed or sought and how related mechanisms are present or absent.

In Figures 3.1 and 3.4 I grouped some illustrative models of communication used in linguistics, semiotics [2], communications engineering, as well as in HCI. This collection of diagrams is intended to show how narrow is the delimited focus of linguistics in relation to communicative phenomena. The juxtaposition is intended to stress similarities and differences among the models. In Figure 3.1 I grouped five diagrams. The first three are from Charles Sanders Peirce, Jacob von Uexküll, and Ferdinand de Saussure, key founders of semiotics and linguistics. The fourth one describes communication as a duct or a pipe where messages linearly flow from source to destination. It is probably the most diffused one. Claude E. Shannon and Warren

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[1] See Appendix E for references that have discussed a bond between Informatics and areas related to communication, including semiotics, hermeneutics, literary criticism, philosophy of language, etc.

[2] See also Figure 4.2, in Chapter 4, for several models of the sign developed across semiotics.

Weaver introduced the last diagram in communications engineering.

Analysing them closely. Figure 3.1(a) depicts an uncommented illustration developed by Charles Sanders Peirce around the mid nineteenth century (Esposito, 1980, p 57, redrawn). Peirce is one of the founders of Semiotics and Pragmatism. In the next chapter, I discuss some issues in Peirce's concepts of the sign. The lack of explanation in Peirce's notes of this diagram does not invalidate the point I am making. In this early sketch. Peirce depicted the relation between reality and sensation as a convoluted activity involving processes related with actuality, regularity, particularization, and "room".

I included this particular diagram, because several models in HCI present the same bi-directional pattern linking processes associated with sensation and reality, such as Norman's model in which goals are linked with physical systems through gulfs of execution and evaluation. Peirce's sketch, however, depicts several possible loops coupling perception to reality. The key point is that the diagram presents the same circular pattern, but to a higher degree of complexity than other models.

In the diagram in Figure 3.1(b). I depict Jacob Von Uexküll's functional cycle. Uexküll was modelling the semiotic relation between organisms and the environment in the early twentieth century. Uexküll also modelled two loops, one internal to the organism, and one linking the organism with its environment. Effector and receptor organs, as well as the inner world of an organism, contribute to the dynamics developed between organisms and their umwelt.[6] The same can be said about the world of action, and the world as sensation. Uexküll is a key reference for those who research the relation between life and communication.

Ferdinand de Saussure modelled human communication as a speech circuit (Saussure, 1983)[7]. Figure 3.1(c) depicts three illustrations of Saussure, to which I graphically represented the domain of linguistics as textually described by him. Although Saussure established the speech circuit, the whole circuit was not the unity of analysis

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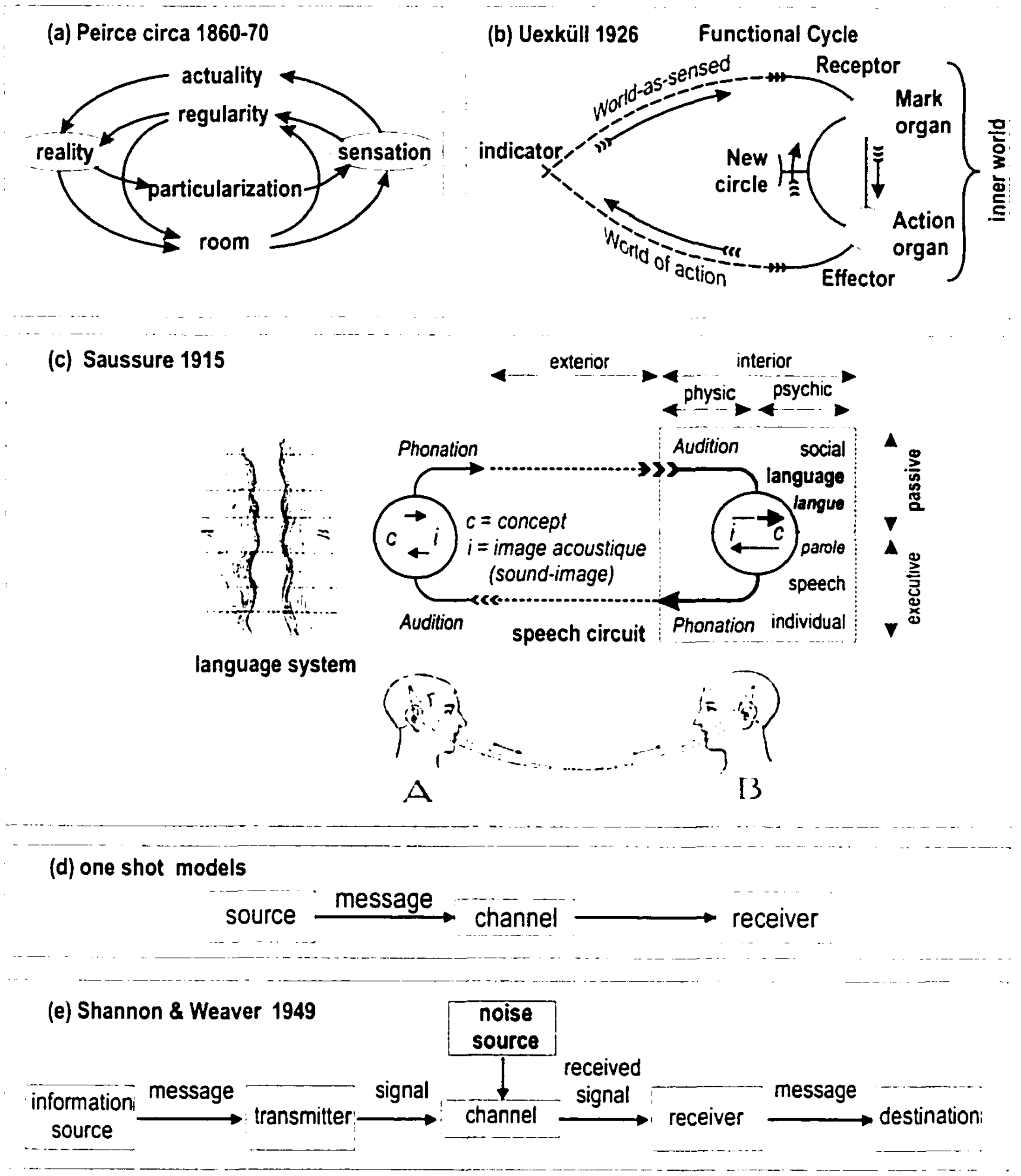
[6] See also (von Uexküll, 1957, 1934, p 10), and (von Uexküll, 1982, p 32), and (Nöth, 1995, p 158) for other subsequent versions of the same diagram.

[7] See also (Nöth, 1995, p 177, redrawn), (Thibault, 1997, p 134,redrawn)



(a) Peirce circa 1860-70

(b) Uexküll 1926 Functional Cycle

(c) Saussure 1915

(d) one shot models

(e) Shannon & Weaver 1949

Figure 3.1: **Models of communication and interaction:** (a) (Esposito, 1980, p 57, reproduction from MS923,redrawn) (b) Uexküll functional cycle of sensorimotor interactions von Uexküll (1926) cited in Cariani (2001) (c) Saussure's speech circuit (Saussure, 1990, pp 19–20) (e) Duct models with one-shot messages (f) Shannon and Weaver's communication model (Nöth, 1995, p 175, redrawn)

of his General Linguistics, or Semiology. Saussure used it to delimit the focus and the boundaries of Semiology to the region depicted in darker grey.[8]

Saussure distinguished the exterior from the interior part of the speech circuit, to exclude the exterior one from linguistics. Within the interior part, he also left out of linguistics the physiological apparatuses associated with audition and phonation. Likewise, most of the concepts on Peirce's and Uexkül diagrams are not included in what remained in linguistics. Until this point, Saussure delimited a interior psychic realm, discarding the remaining parts. It is possible to say that he followed a long tradition of separating the mind from the body, in which existence is subservient to thought.

In addition, he also distinguished what is passive from what is executive. He associated passive with what is "social" and homogeneous, characterizing it as "langue" (language). He discarded what is individual and heterogeneous as being active, characterizing it with "parole" (speech). Henceforth, linguistic's realm of interest, according to Saussure, is limited to what is passive, ideal ("psychic"), and homogeneous. In another diagram, Saussure represented the mapping between concepts (c)and sound-images (i). This mapping is on the left part of Figure 3.1(c) linking two amorphous regions. In Saussure's framework, there is no place for what is active, concrete ("physiological"), or heterogeneous.

However, linguistic phenomena also change over time, even if passive and homogeneous. But Saussure also distinguished the relations between things that do not vary over time (synchronic) from those that vary over time (diachronic). His interest was focused on those things that do not vary over time. To what remained, he added a notion of structure. This was in accordance with his approach, which assumed that the parts could be studied independently of the whole. The school of thought that follows him became known as *Structuralism*.

Saussure's distinction is only an example of many similar distinctions such as signified/signifer, content/expression, sense/reference, subject/object and many oth-

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[8] See (Saussure, 1990, pp 19 23) for Saussure's description of the place of language within linguistic facts.

ers found in language and logic studies, from Augustine (397) to Jakobson (1968).[9] With these epistemological cuts de Saussure left out of the study of language actual dialogues, people, dialects, everyday language, language use, slang, practice, power, interaction, and anything else that could address difference and heterogeneity. From a research point of view the delimitation of language as an isolated system has been very well received. It was very effective, indeed. Structuralism turned out to be the dominant paradigm in language studies. Difference is difficult to generalize, if not impossible. However, Saussure's framework had a place to discard what was inconvenient. Everything that could eventually bother the general structure of language was swept under the "parole" rug in the name of scientific objectivity. In Figure 3.1(d) is a diagram that models communication as a unidirectional channel linking source and receiver. Saussure's restricted linguistic realm, in which sound is mapped onto concepts, is in accordance with this unidirectional model. It is also in accordance with the notion of cause-effect so characteristic of Western culture.

I agree with Rogers, for whom linear models of communication facilitate understanding in function of their simplicity and mechanistic concept of the communication act, but also deeply distorts reality, not showing what happens before or after it. Worse than that, "they may imply an autocratic, one-sided vision of human relationships", one in which the receiver assumes no active role in the communicative process, suggesting a relation of domination or manipulation of the source over the receiver (Rogers and Agarwala-Rogers, 1976, Chapter 1). Although several alternatives have emerged, the Cartesian hegemony, so well represented by Linguistics in communication and by information processing models in Informatics, continued to annihilate difference, alterity, disagreement, incertitude, instead of learning from it.[10]

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[9] See (Nöth, 1995, p 88,94) for examples and a discussion on dyadic and triadic semiotics.

[10] Around 1919-21, Bakhtin (1993) started a long career in which he discussed topics concerning authorship, participation, and responsibility, all subsuming the importance of difference in human action. Peirce himself did not succeed in explaining his broad concept of sign. As I explore in the next chapter, the understanding of Peirce's work is problematic until now. Many other authors have stressed the importance of action to communication, interaction, and cognition. A short list may give the reader a rough idea of the disciplines in which these authors have worked as well as the

In 1949, Claude Elwood Shannon and Warren Weaver were interested in the optimization of electric communication channels and proposed a Mathematical Theory of Communication in which a noise was added to the system, in addition to an information source, a transmitter, a channel itself, and a receiver Shannon and Weaver (1949). See Figure 3.1(d) (Shannon and Weaver, 1949).

In fact, the cornerstone of Shannon and Weaver' s information theory is the concept of noise, rather than its linear structure. The addition of a noise source and its conceptual understanding as basic to the concept of information enabled engineers to actually include noise and difference in the design of communication systems. Before that, noise was something difficult to conceptualize and even consider. Inside the black boxes, however, analog circuits continued to be the basis for the project of amplifiers (e.g. used in receivers and transmitters) and transmission lines (channels). Sources of energy were taken for granted. Moreover, the area of control systems, with its focus on the dynamic interactions between elements of a systems, continued to develop.[11]

The diffusion of Shannon and Weaver's model, however, had opposite consequences in the technological and human sciences. In engineering it brought to its practices the feasibility of managing difference. Shannon and Weaver did not intend to model meaningful information. In Linguistics the linear structure of Shannon and Weaver's model only reinsured the prevalent hegemonic view, reinforcing the bias against difference and heterogeneity. The model that was in fact being sustained was not Shannon and Weaver's in its full complexity, but the ancient pipe-like model of communication.

Computer science emerged at the confluence of Linguistics, Mathematics, and

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time in which their work became available in English. I would include in this list authors such as Wittgenstein (1997), Austin (1962), Bourdieu (1977, 1990), Vygotsky (1978a,b) Iser (1978), Jauss (1982), de Certeau (1984), Habermas (1984), Bruner (1990), and Strauss (1993). The disciplines include philosophy, sociology, literary criticism, and psychology among others.

[11] Only at certain levels of abstraction and for certain purposes is it interesting to model electric circuits as chains of consecutive boxes. Even when that happens, the engineer is aware that all the parts need to match each other.

Engineering, and it was fuelled by a myriad of activities across fields that were feasibly computerized and automated. The abstract computing machine is an information processing model that deterministically does one thing at a time, is closed and isolated from its environment, and has a rich and decomposable structure. This delimited realm of computing coincides not only with the Linguistic realm charted by Saussure, but also with the realm chosen by Chomsky to delimit his interest in syntactic structures. The delimitation per se is not problematic. There are also nondeterministic machines. But it becomes a problem when one believes that these isolated parts are able to account for every linguistic or computational phenomena. Then, it becomes reductionist.

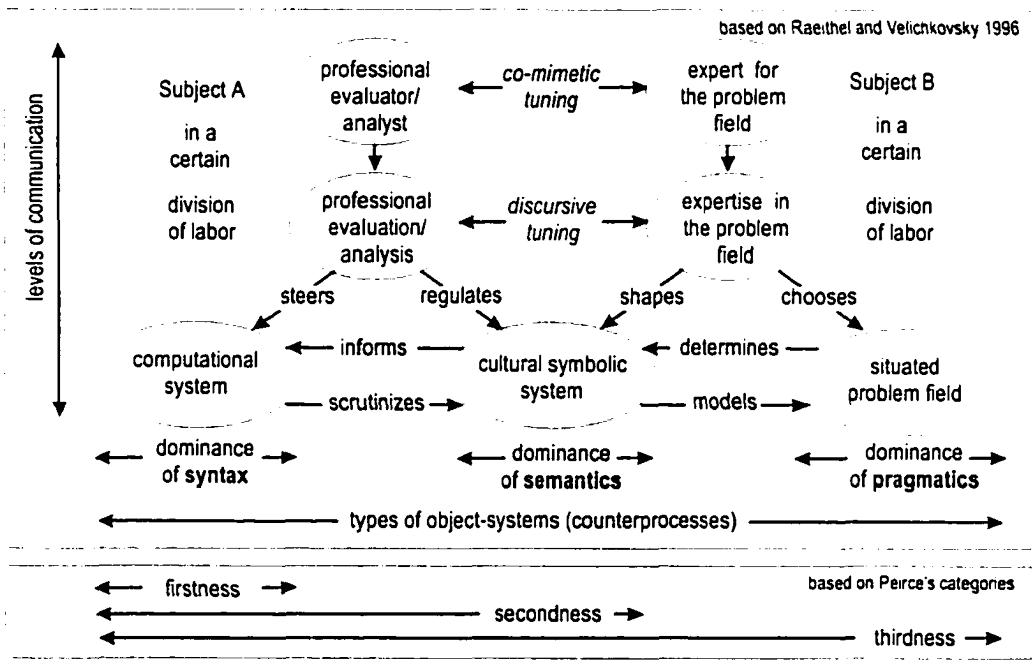

Figure 3.2: **Raeithel's model of interaction between designers and specialists:** based on (see Raeithel and Velichkovsky, 1996, p 228) and Peirce's categories.

An illustration developed in (Raeithel and Velichkovsky, 1996, p 228), and depicted in Figure 3.2, describes the different realms of syntax, semantics, and pragmatics in the context of information systems, as corresponding respectively to computational systems, cultural symbolic systems, and the situated problem field. Other authors organize these and other realms differently, such as Peirce's categories of firstness, secondness, and thirdness.[12]

In practice, however, computers are open, interactive, and people hope that they can mediate meaningful activities. Not only does their architecture have a deep influence on the activities they support, but peoples' activities influence their development.[13] Research both in Informatics and in HCI have been addressing dissonance among the theoretical models which continue to model the computer as an isolated machine, and the actual practices which situate computers as deeply coupled to the environment. The main objective of this section was to bring awareness for the rich spectrum of models of communication, and the legacy that they represent.

It is not because a model comes from semiotics that it will bring novelty to Informatics, and vice-versa. In the following section, I address some models proposed in Informatics that open the computer to its environment, returning to the realm of HCI later on.

3.2 Interactive Machines

In this section, I narrow the scope of the discussion to the realm of computer science. While in the previous section I have shown how linguistic phenomena was cut off from the world, now I show how this perspective is too simplistic even to describe computing machines. In order to do that, I briefly present the concept behind interactive machines (Wegner, 1997) and evolutionary robotic devices (Cariani, 1991a,b,c). These models break with the isolation of the artifact and structurally couple them

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[12] As I discuss in the next chapter, certain definitions of syntactics, semantics, and pragmatics model them inclusively (pragmatics contains semantics, that contains syntactics), rather than exclusively (as if they did not intersect). This distinction does not interfere in the argument I elaborate here because in either case, the computer realm corresponds to the realm of syntax, the narrower one.

[13] Even performance models measure how fast computers are on certain activities like integer and floating point calculation, I/O speed, graphic visualization, etc. indicating different computers for different activities.

with the world they are part of.

It is necessary to note that throughout the discipline of computing it is becoming evident that even the most established canons have theoretical and practical constraints. Wegner criticized the rationalistic approach adopted in computer science, making a reference to the paradigm shift occurred in physics from rationalism to empiricism, and claiming the necessity of a similar shift in the discipline of computing from algorithms to interactions (Wegner, 1995a). He expressed this belief pointing to the construction of an empirical computer science, which he said, would be in accordance with interactive computing [14]

Peter Wegner has extended the notion of what is computable by showing that computing systems present more complex behaviors than what Turing machines can represent. Turing machines are closed, non-interactive systems. Turing machines are the theoretical models that serve to analyze algorithms, computable functions, and computational complexity. As such, Wegner shows that they are not powerful enough to capture the interactive behavior of objects, software systems, and distributed computers over time. According to him "Turing machines can be extended to be interactive by adding input actions supporting external inputs during computation. This simple extension transforms Turing machines from closed to open systems, extending their expressive richness to that of objects" (Wegner, 1995b, p 70). See Table 3.1 for more details on the inner workings of interactive machines, and Wegner's references to syntax, semantics, and pragmatics.

In this sense the extension from algorithms to interactions break with accepted models and with the conceptual boundaries that delimit what computations are. Firstly, it breaks with the idea that Turing Machines are equivalent to computing. It does that by showing that Turing Machines do not capture certain computational behavior that interactive machines have. Secondly, it breaks with the myth that abstractions are universal, because it recognizes that interactive machines are limited. Wegner illustrates this point through layers of increasingly restrictive abstraction. The Turing machine abstraction, which correspond to closed algorithmic systems,

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[14] See Wegner (1999), Goldin et al. (2000), and Goldi and Keil (2001)

Peter Wegner indicates the possibility of extending closed systems (logic) through the inclusion of pragmatic components that are able to modify the world (dynamically evolving structures) to which they have access (Wegner, 1999). Interfaces, which are the building blocks of interactive machines ... "express the mode of use or pragmatics of an interactive system, complementing syntax, and semantics" and overcome "the goal of expressing semantics by syntax" by replacing it "by the interactive goal of expressing semantics by multiple pragmatic modes of use"(Wegner, 1997, p 85-88).

The Chomsky hierarchy harnesses an equivalence between automata, which are state transition mechanisms that recognize input sequences, and grammars, which are mechanisms of generation (grammars) of strings (sequences of symbols). Wegner refers to automata and to grammars respectively as "listening machines" and "speaking machines"(Wegner, 1995b, p 321). It is a hierarchy because several of these equivalencies between machines and behavior are aggregated within distinct strata. The broader strata contain the relationship between Turing Machines and Unrestricted Grammars. In the interest of mathematical tractability, computer scientist's have left out from their analysis important computational behaviors (Wegner, 1995b, p 71) that usually lay beyond the broader strata of the Chomsky hierarchy. The intuitive notion that computation corresponds to what Turing Machines can compute, known as the Church thesis, has been accepted for fifty years. This restriction holds mechanisms (automata) and their behavior (formal languages) together within the limitations of what can be formalized. Wegner parallels it to the restrictions of first order logic in relation to second order logic.

Consequently, his extension shows that the models accepted for half a century for describing computing phenomena are not powerful enough to capture interactive behavior over time, to capture what computations really are. Wegner says that "Fixing the modelled world and expressing the pragmatics in terms of the modelled world reduces interactive models to noninteractive closed systems and correspondingly reduces empirical to rationalist models." As in other areas, such as linguistics and anthropology, this kind of restriction was more in the interest of the computer scientist, the anthropologist, the linguist, than in the interest of Informatics, culture, and communication.

The mathematical restrictions mentioned above refer to the fact that Interactive Machines have no sound and complete first-order logic descriptions. They can be specified only through second-order logic with no adequate proof theory or completeness properties. Interactive machines wrap around Turing Machines and clearly admit their incompleteness, and consequently their restrictions as universal models. In this sense, interactive machines are richer, but they also have their costs in terms of mathematical rigor. They are only able to express "the partial behavior of a subset of the set of all possible interactions." (Wegner, 1995b, p 46). "The correctness of interactive models is not merely difficult but impossible."

Table 3.1: **Wegner's interactive machines**

has a stronger restriction than interactive machine abstractions, which correspond to open interactive systems. However, none of them, not even interactive machines, is capable of capturing the behavior of actual digital computers: they are not universal (Wegner, 1995b, p 71).

Wegner's work partially breaks the traditional boundary between theory and practice so often found in the discipline of computing. It is also in accordance with Wegner's beliefs on the need to overcome philosophical rationalism with philosophical empiricism in order to ground an Empirical Computer Science, as has happened in physics, for example. In order to substantiate how computing phenomena encompass more than non-interactive algorithms, he compared several topics in the discipline of computing across his writings in order to illustrate how their behavior is richer than what can be grasped by traditional computing models. It is interesting to see traditional models of computing in relation to Saussure's epistemological cuts discussed earlier. Computer scientists not only embrace the delimited scope, but make it universal, taking the part for the whole.

To conclude this section, I present some models developed by Cariani (1991a,b,c) of robotic devices in which concepts of syntax, semantics, and pragmatics are used as a scaffold to compare different models of computing and robotic machines. See Figure 3.3.

Cariani (1991a,b,c) proposed machine architectures in which the hardware and the software are contingent on syntactic, semantic, and pragmatic factors. Cariani provides a framework in which different machine architectures can be evaluated in function to the degree and the mode they are opened to the environment. Cariani's evolutionary devices complement Wegner's interactive machines by making explicit the interconnectedness of syntactics, semantics, and pragmatics in computing models.

In this and in the prior section I addressed how both machines and humans have been cut off from the world in which they exist and interact.[15] In the next section

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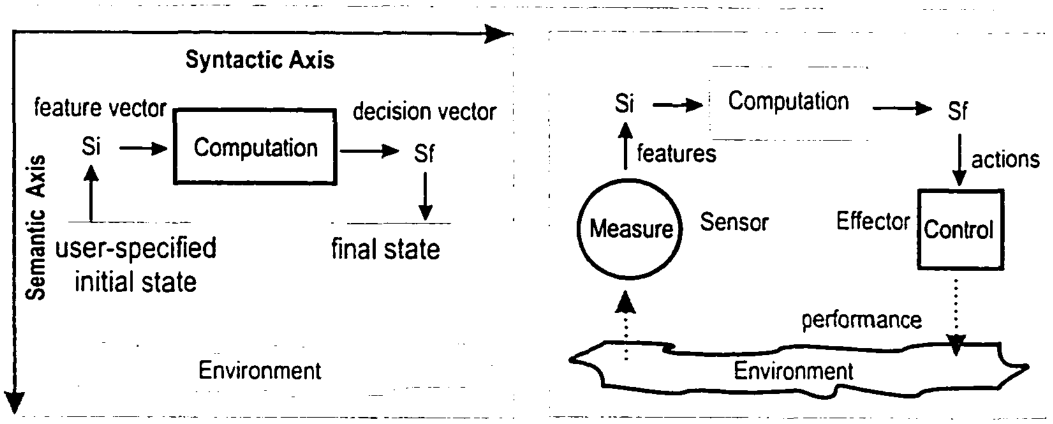
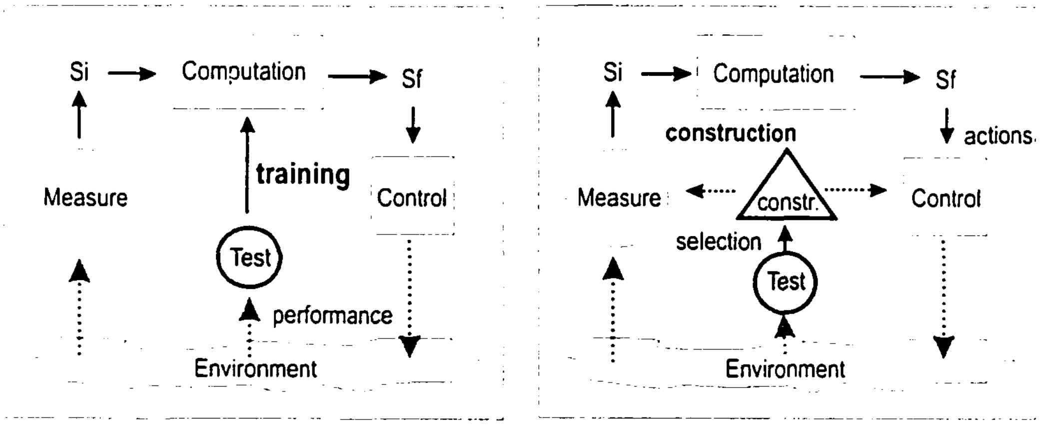
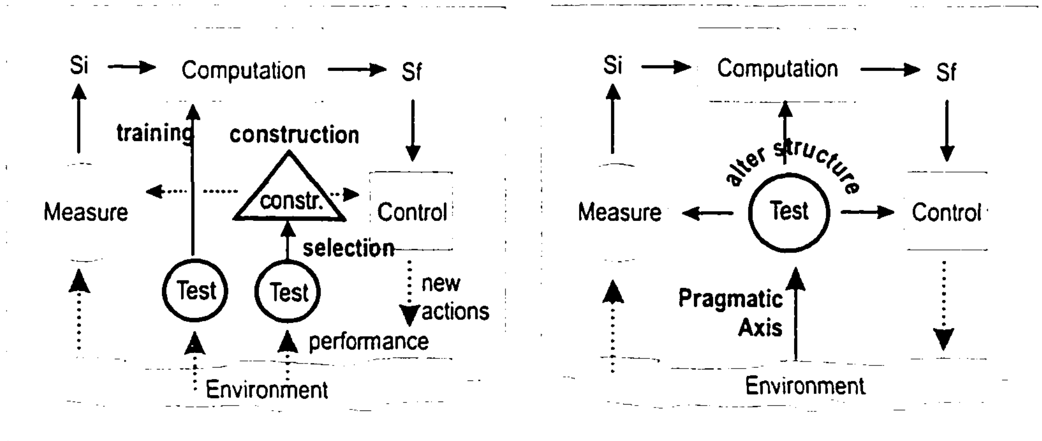
[15] The information processing model is a perspective in the cognitive sciences that uses the isolated computing machine to model cognition. Information processing models have also been criticized as too reductionist. See Appendix D for alternative approaches.



(a) Non-adaptative computational device **(b) Non-adaptative robotic device**



(c) Syntactically adaptive robotic device **(d) Semantically adaptive robotic device**



(e) Semantically and syntactically adaptive robotic device **(f) Evolutionary device**

Figure 3.3: **Cariani's robotic devices** based on Cariani (1991a,b,c)

I address models of interaction between humans and machines, as developed in the HCI literature. Some of these models freed people and machines from their isolation. However, they also remained somehow limited and isolated from their context.

3.3 Interaction Models in HCI

The tendency for Informatics and HCI to stratify, which is discussed in Chapters 1 and 2 and which gives support to the concept of cultural niche, is also identifiable in the disciplines of the arts and humanities that have language as their main subject matter.[16] In language studies emphasis on structure rather than use[17] co-developed and it is one of the supports for the differentiation between linguistics and literary criticism, for example.

As I discussed in Chapter 1, Informatics has developed a similar kind of hierarchical cultural organization in which *structure* has been given preponderance over *use*. One of the arguments for the introduction of computer languages sometimes were based on the easiness of programming, due to programming language's similarities with natural languages. However the main constraints that have prevailed in the design of such programming languages have been the ones associated with syntax, in opposition to semantics and pragmatic constraints. This dichotomy between structure and use recursively organizes professional practices enacting similar distinctions between hardware and software, software and applications, and applications and use. Indeed, most information technology continues to support the exclusion of human issues from its foundations.

Historical disciplinary development is not always continuous, as I have depicted explained in the previous chapter. It is discretely incremental.[18]

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[16] See, for example, Eagleton (1983) for a historical critical assessment of the development of literary studies.

[17] Structure and use are directly related to Saussure's distinction of *langue* and *parole*.

[18] See Christensen's concept of break-through technologies in the following section. He analysis how diverging practices in product development are usually overlooked by mainstream tendencies. There are several examples of diverging practices that have overgrown mainstream ones, turning

Across the traditional rationale within which Informatics is grounded. HCI would be located at the bottom and at the end of the professional hierarchy and production chain. The focus of informatics is still on structure, rather than use. From a short-term product-centered world view, a pleasant and attractive appeal is usually a later addition to the already conceived and developed product.

Truly, HCI is an example of a diverging force in Informatics in what concerns human-machine communication and interaction, questioning priorities and horizons. I characterize HCI as diverging, instead of as revolutionary, because a critical analysis of its main theoretical frameworks is in deep agreement with the above traditional rationale that hinders its development. The still small differential factors that characterize its divergence are associated with human structures and human agency. The focus is the activity that a artifact supports, not just the artifact. These factors are part of the foundations on which the involved communities are consolidating HCI's identities, such as human factors, HCI narrowly understood, and CSCW, as well as on the models adopted by the community.

It is in this light that I compare some models of interaction proposed in HCI. I grouped four diagrams in Figure 3.4. The first one is from Douglas Engelbart's project of augmenting the human intellect. The second and third ones are from Donald Norman's cognitive engineering, in which one was used to contextualize the role of the designer in technology production and the other to delimit the main human action when supported by computers. The last diagram group illustrations developed in Semiotic Engineering by Clarisse Siekenious de Souza and Jair Cavalcanti Leite. This last illustrates a refinement of one of Norman's models, and it exemplifies converging tendencies in communication and diverging forces yet to be included in the understanding of interaction. These four diagrams in Figure 3.4 are intended to support the argument that it has been very difficult for HCI people to break with Informatics' product-centered legacy.[19] In the following paragraphs I explain each of

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mainstream themselves .

[19] The historical legacy of Linguistics on the development of Informatics is an interesting topic, as I have already stressed. It is an open question for me how much the adoption of models developed

these diagrams.

An early example of a theoretical framework based on a bi-directional relation between human and machine processes was proposed by Douglas C. Engelbart in his project of augmenting the human intellect (Engelbart, 1962, 1986). Engelbart proposed it during a period in which cybernetics was at its apex. Engelbart's model, reproduced in Figure 3.4(a), remained on the outskirts of the discipline, as did his main theoretical framework.

Cybernetics studies communication and automatic control in artificial and living things. The interesting aspect of Engelbart's diagram, is that it models both human and machine processes as open systems that are coupled with the world. Besides the historical relevancy, I have included Engelbart's model here in order to enable a comparison with Norman's gulfs depicted in Figure 3.1(b). Considering the same level of abstraction, Engelbart modelled human-machine processes as open and circular systems. Norman modelled them as closed.

In the period between Engelbart's and Norman's work, the communities in Informatics have consolidated the product-centered perspective. At the same time that the demand for automation increased there was no favorable space for interaction in theories, practices, attitudes, and everything else that structured the discipline. However, not everybody remained comfortable with this contradictory course of development. The historical disciplinary transformations discussed in the introductory chapters illustrate this point.

Donald A. Norman, working as a cognitive scientist, proposed a theoretical framework which he labelled Cognitive Engineering (Norman, 1986). At this point, HCI had acquired momentum and already had its own conferences and publications. This does not mean that HCI had attained space and recognition within Informatics. It remained on the outskirts of Informatics. HCI found a more favorable environment with cognitive psychologists, most working in cognitive sciences, and supporting the information processing paradigm of cognition but who were not members of the In-

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in language studies has been contributing to Informatics to enlarge or to narrow its realm, and vice versa.

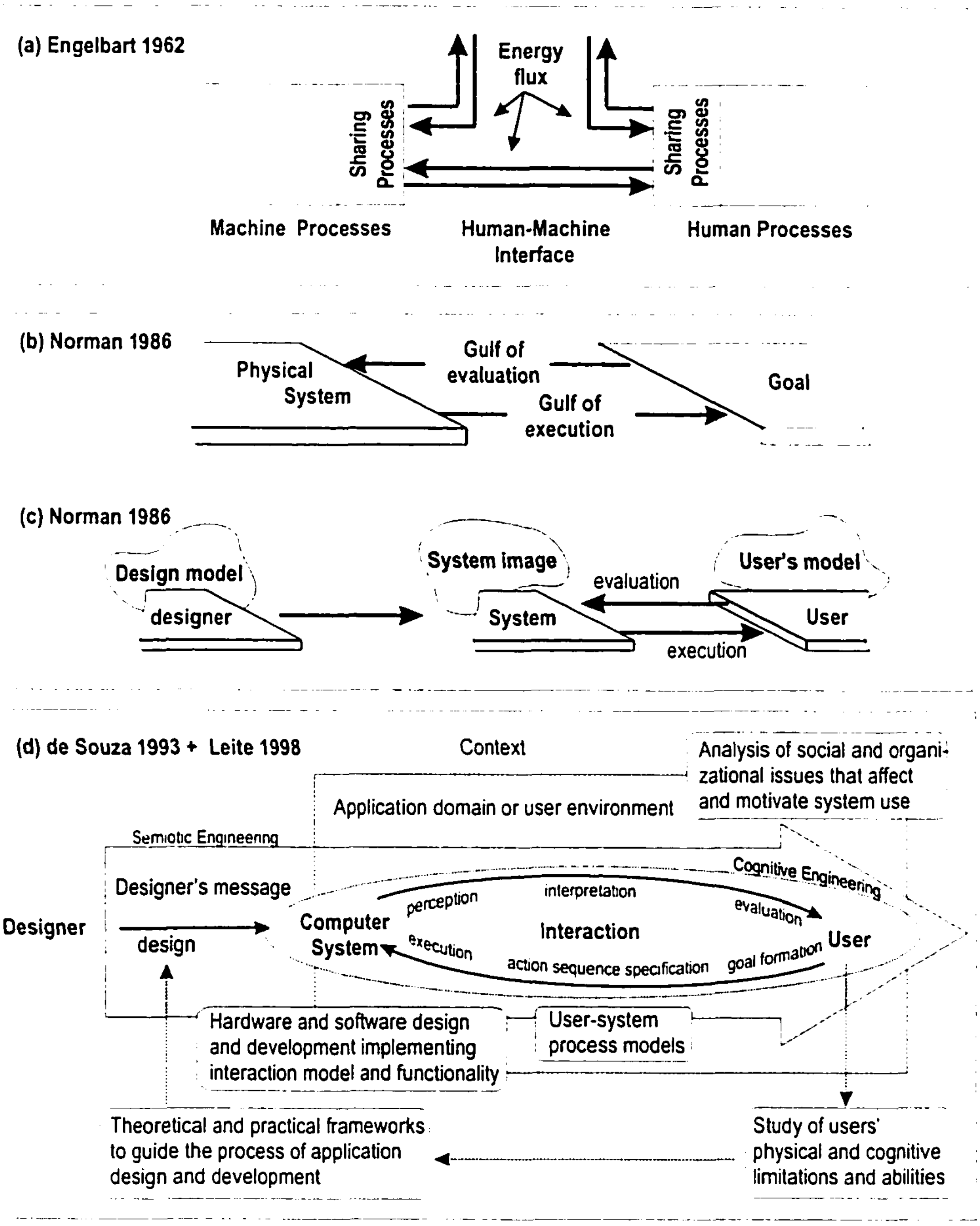

Figure 3.4: **Models of communication and interaction:** (a) Engelbart (1962, 1986) (b) Norman's Norman (1986) (c) based on de Souza's model in Semiotic Engineering (de Souza, 1993) and (Leite, 1998, p 13–70)

formatics community. It is not by chance that in the rank listed in the initial chapter, computer scientists are labelled "converts".

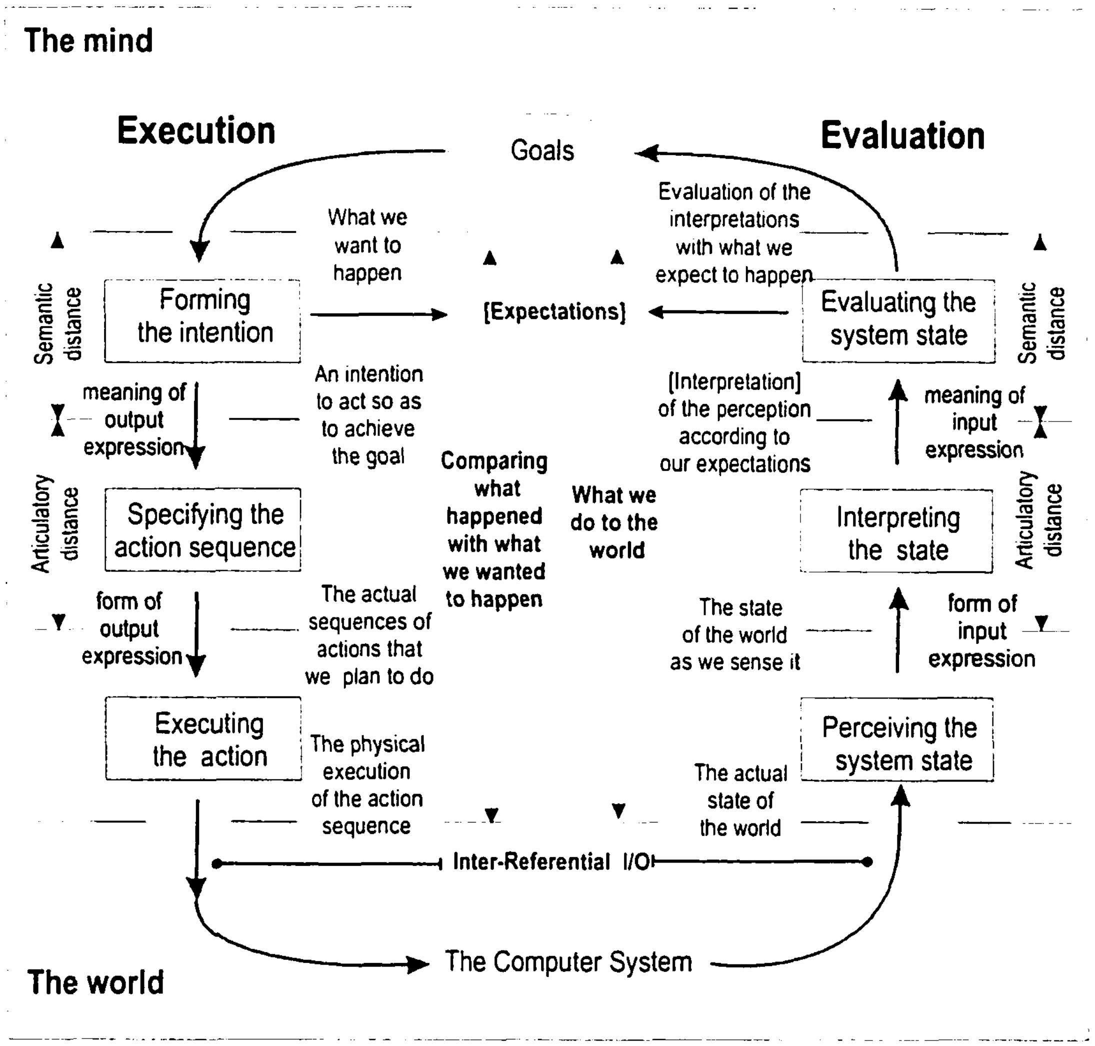

Figure 3.5: **Norman's interactive cycle of execution and evaluation**: based on Hutchins et al. (1986, p96,111) and Norman (1990, p 47).

As I said, HCI development has been incremental. Compared to the universal but isolated concept of computing product, Norman's gulfs, depicted in Figure 3.4(b), opened the artifact to the world and rescued the circular nature of interaction. Norman's model remained focused on a single individual, a single computer, and a linear, sequential circular structure of action. Norman only partially rescued the circular nature of human action. Norman subdivided users's action on a gulf of execution and a gulf of evaluation, both bridging the physical system and the user. I said "partially rescued" because a closer look at his proposed framework shows a blend of circular and linear models. In Figure 3.5, I represent the main elements of Norman's gulfs of execution and evaluation.

Each user task cycle is subdivided into several activities or phases. Norman calls them stages. The primary phase is the establishment of goals. Once a goal is established, three phases are necessary to carry out an action: forming an intention in accordance with the established goal, specifying the sequence of actions that will perform such an intention, and executing these actions.

The assessment of the action effects upon the world or computer system also demands three phases, which are somehow complementary to the other ones: perceiving the world state (which is complementary to acting on it), interpreting the state (which is complementary to specifying the action), and evaluating the interpreted state (which is complementary to forming the intention).

Norman's task cycle and the associated gulfs are grounded on a concept of interaction that subdivides every "expression in the interface language" into "meaning and form". Similar to de Saussure's model in which the role of language was related to the link between concepts and sound-images, Norman's model bridges the cognitive realm with the world realm. However, Norman's gulfs include both activities associated with evaluation (like Saussure) and activities associated with execution (discarded by Saussure). This rescues the individual cognitive processes and places them in the realm of HCI, beyond the realm of Informatics.

Behind Norman's subdivision of the user task cycle are the notions of semantic and articulatory distances. In semiotics and language studies, including linguistics, the common use of the term semantics refers to the relationship between the form of an expression the object it stands for. In Norman's framework, semantic distance reflects the relationship between user intentions and the meaning of expressions in the input and output interface languages. Meaning and form are assumed independent and established by convention. Articulatory distance reflects the relationship between the physical form of the expression in the interaction language and its meaning.

In relation to Saussure's speech circuit, the articulatory and the semantic distances could be said correspondent to the physic and the psychic interior parts of the speech circuit, respectively. Compare Figures 3.1(c) and 3.5. Indeed, Hutchins et al. associate semantic distance with the phases in which a intention is structured or a system state is evaluated and articulatory distance with the phases in which a sequence of actions is specified or a system state is perceived (Hutchins et al., 1986, p 100,111). This implies that meaning and the objects for which the input and output interaction languages stand are still inside people's minds.

However, Norman included different models for the designer, the user, and the system under design or use, as depicted in Figure 3.4(c). This implies that he was open to a broader context but chose to stress certain elements in his core model. For example, in what concerns design processes, the role of the user continues to be passive compared to the role of the designer.

A semiotic approach to design in Informatics cannot be restricted to the realm of the mind. Hutchins (1995), who co-authored one of the articles with Norman, later studied the role of objects outside the mental realm in cognitive situated activities. Norman is employed Gibson (1979)'s concept of affordance, which directly relates people to their environments.[20]

In some illustrations of the gulfs, but not in all of them, Norman also includes a link between the two gulfs associated with "expectation activities" (Hutchins et al., 1986, p 96), and inter-referential I/O (Hutchins et al., 1986, p 111). As defined, the concepts of semantic and articulatory distance have no explanatory power to scaffold the roles of expectations, inter-referential I/O, as well as the complementarity of phases across the execution and the evaluation gulfs. In this sense, Norman's model

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[20] The concept of affordance was developed by James J. Gibson (1979), in environmental psychology, and it addresses the relation between organisms and environments (worlds and actors). Norman himself has introduced affordances in HCI (Norman, 1990) but the concept has been mostly misunderstood by the community as a product attribute, and not as a relation between people and artifacts (Norman, 1999).

is too limited for the idea of planning ahead, leaving no space for activities related to learning by experience. It also gives no hints about the origins of goals.

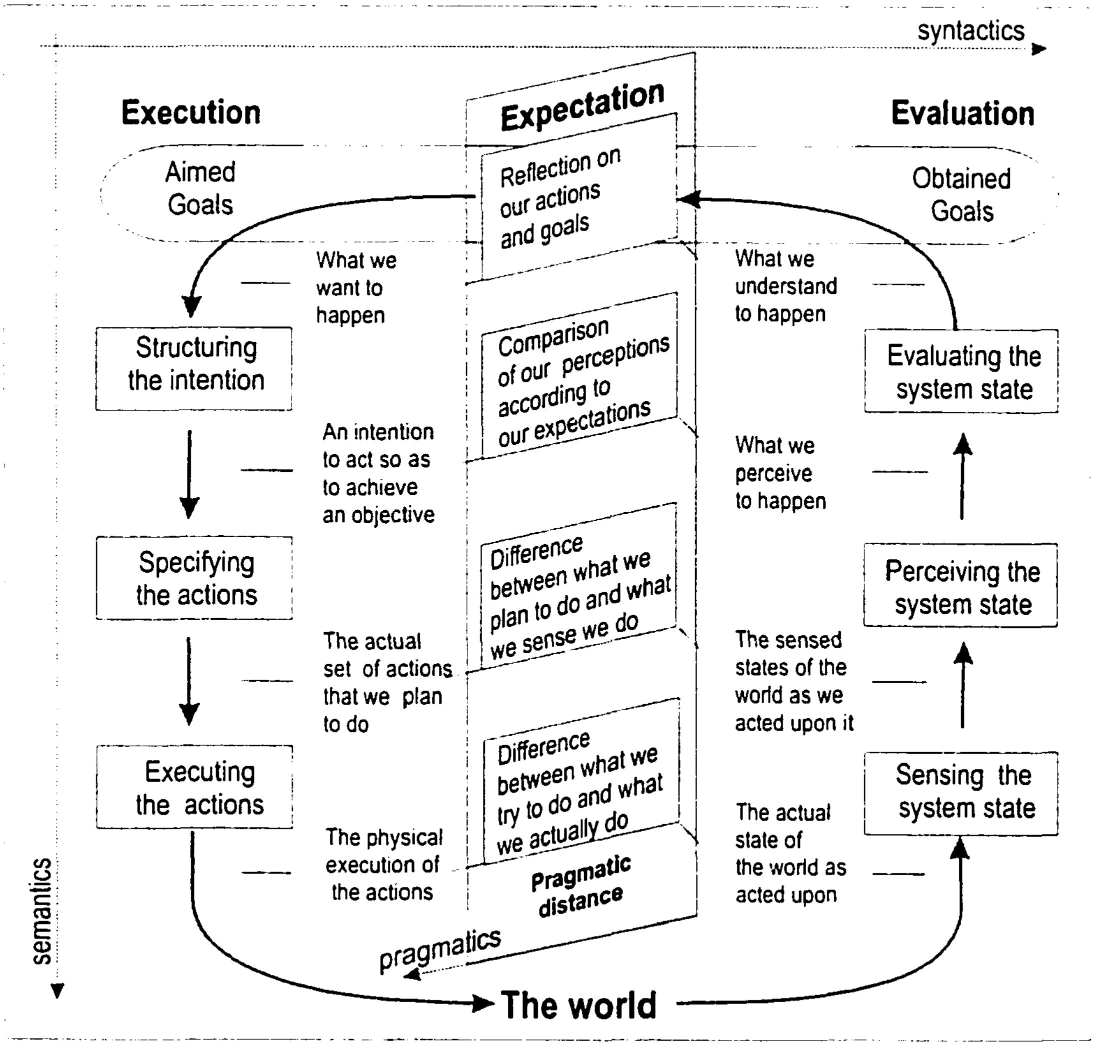

Figure 3.6: **An additional gulf of expectation**

In Figure 3.6 I propose a reorganization of Norman's gulfs considering: (a) Cariani's framework;[21] (b) my understanding of the interrelationship of syntactics, semantics, and pragmatics; (c) the need to open the cycle to the environment; (d) action understood as reflective practice (Shön, 1983); and (e) the possibility of conceiving

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[21] The models of evolutionary devices developed by Cariani and only briefly commented on in the last section may bring light to the role of syntactics, semantics, and pragmatics to model computer mediated users's actions. See Figure 3.3 and Cariani (1991a,b,c).

action as having different levels as in Activity Theory. I have maintained the main cycle as a scaffold, but I should remark that the addition of a pragmatic dimension, and an extension of the semantic distance toward the outside world, enables other cycles of interaction within and beyond this one.

I decided to add this illustration in favor of those who use Norman's gulfs simultaneously with a semiotic framework. The framework, however, continues to be limited to the interaction of a single individual interacting with a system, although it opens an interface through a third pragmatic dimension. In a subsequent section, I extend the HCI 3D conceptual model proposed in the preceding chapter with the inclusion of non-deterministic elements. I close this section with a comparative analysis of the previously discussed models of communication and interaction.

Continuing with a comparison of the models included in Figure 3.4, de Souza further developed Norman's conceptual model of design. In Figure 3.4(c) I grouped models found in (de Souza, 1993) and in (Leite, 1998, p 13-70) developed for Semiotic Engineering.

De Souza called her approach Semiotic Engineering (de Souza, 1992, 1993). The main rationale embraced in Semiotic Engineering frames design as unidirectional messages sent from designers to users. Although the main model of Semiotic Engineering is still linear, it tends to a broader focus than Norman's original model. Firstly, the focus is shifted to a broader scope embracing the designer and user. Secondly, it explicitly situates the "message" within the broader organizational context. And thirdly, in some versions it includes a feedback loop that goes from the "user" to the designer. However, the processes associated with this feedback are still in the designer's realm of competence.

The models just described of Norman and of de Souza illustrate the incremental and stepwise nature of disciplinary development. Sometimes, a small shift of focus, or change of scope, is enough to nurture a different line of research. For example, Norman added a human element to the isolated computer, but remained limited to the individual mind. Indeed, the semantics of Norman's model is situated in a mental realm in accordance with the information processing paradigm. This is acceptable in the closed realm of the computing machine. However, the semantics of interactive machines should go beyond that limit. Indeed, Norman's use of the concept of affordance concerns the relation between organisms and their environment Norman (1999). Similarly, the rationale behind Hutchins' 1995 distributed cognition breaks the isolation of thought as something limited to the individual, distributing it across the objects that mediate human activity.

Andersen's Computer Semiotics, as illustrated in Figure 2.4 in the previous chapter, explicitly embraced structuralism, without discarding other perspectives. It complemented the framework with the semiotic relation between subject and object, but remained limited to an understanding of language as a system, leaving far from its emphases individual and social factors. In this sense the use of semiotic structuralists' paradigms in Informatics and HCI rescue part of the heritage that traditional Informatics neglected in its recent past. Similarly, De Souza considered the designer and the message as the focus of her study, extending even further the scope to be considered in HCI, but remained limited to one-shot messages.

In the case of HCI and communication, the culture centered on the artifact constitutes heavy ballast that although giving stability to Informatics also hinders its joint development with other disciplines. Contributions from Cognitive Engineering (Norman), Computer Semiotics (Andersen), and Semiotic Engineering (de Souza) illustrate the slow enlargement of HCI's realm. These contributions also illustrate how difficult is to overcome existing disciplinary orthodoxy present in HCI and Informatics' cultural ecology. The models above, however, are still limited in scope with respect to cultural, social, historical and factors.

In practice, however, the few researchers I mentioned all went beyond their embraced theoretical framework, enriching their work with foreign elements such as environmental, organizational and contextual issues. Despite the victories, there are large chasms among HCI theories and practices in what concerns the relationship between meaningful design, human agency, and communication. From one side HCI and Informatics people are only beginning to explore the field of communication and semiotics in their disciplinary realm. From the other side most of the models in semiotics have not been systematized enough to give a solid base for experimentation and reflection.

In the next two sections I shift the focus of discussion to an even broader scope, the organizational level. I present the area of technology diffusion as communication processes together with several attempts to capture the dynamics of such processes in multidimensional organizational models.

3.4 Diffusion as Cultural Transformation

The practices present in a community are deeply grounded in the mastered, shared and distributed culture among its members. The diffusion of new and the abandonment of old practices, beliefs, and artifacts across societies and organizations is a topic studied and often labelled as diffusion research. Professional interventions are always a blend of modification and persistence, of development and maintenance, of orthodox and heterodox forces (Bourdieu and Wacquant, 1992), or of centripetal and centrifugal tendencies.(Bakhtin, 1981, pp 272-3).[22]

Diffusion research also deals with the relation between people and technology, but within a broader and shallower context than HCI. In reference to the nature of HCI, diffusion research is concentrated at the organizational and the social levels. For example, diffusion research has a broader scope than usability and interaction studies because it is more open to encompass the motives behind the acceptance or the rejection of changing vectors across established practices simultaneously. Therefore, diffusion research may be interesting to HCI because it may represent a possible frame of reference from which interaction design and usability evaluation can be understood and contextualized. Usability presupposes use, but the cases in which there is *no use*, because diffusion did not happen or because it was rejected, are difficult to addresses

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[22] In my opinion, to talk about change and revolution without talking about maintenance and conservation is propaganda. It is like coordinate systems without references. It is very effective however, because the social and cultural structures that are indeed maintained by the fast changing material process are not even questioned, despite their associated cultural and environmental losses.

in traditional frameworks that grew out of product-centered approaches.

According to Everett M. Rogers, the same author who I mentioned above criticizing linear models of communication, the diffusion or the lack of diffusion occurs through communicative processes among the members of a social system. "Diffusion is a kind of social change, defined as the process by which alteration occurs in the structure and function of a social system. When new ideas are invented, diffused, and adopted or rejected, leading to certain consequences, social change occurs." (Rogers, 1996). Rogers understands communication "as reciprocal and transactional, not a unidirectional flow, as most oversimplified models of human communication seem to imply"(Rogers and Agarwala-Rogers, 1976, Chapter 1).

Several factors contribute to the degree in which novelty is fully incorporated within or completely rejected from a culture in transformation, including its social structure, its norms and sustained practices, its cohesiveness, its awareness for deficiencies, and its associated risk. In Rogers' theoretical framework, as illustrated in Figure 3.7(a) the elements of diffusion processes are: a) social systems in which b) an innovation is introduced and communicated c) across its members d) over time. These factors depend on communicative, social, economic and historical characteristics, and vary across individual members and groups. Rogers conceptualized five main phases to structure the diffusion-decision process: (i) knowledge, (ii) persuasion, (iii) decision, (iv) implementation, (v) confirmation.

In Figure 3.7(a) these phases correspond respectively to: (i) awareness of foreign practices or artifacts, (ii) negotiation through which a decision is grounded or informed, (iii) the decision itself, (iv) trial or deployment of the foreign practice within the established culture, and (v) the cultural incorporation of the practice or artifact. These phases are usually temporally ordered, but exceptions may occur, such as when a decision to adopt comes before negotiation. For example, the CEO of an organization decides to use e-mail as the main form of communication instead of memos. Different people across the organization may have contradictory perspectives about its adoption.

The s-curve in Figure 3.7(b) is a well known diagram in diffusion research. The s-curve plots the percent of individuals who adopt a practice or artifact as a function of time. Initially, only a small number of individuals incorporate the innovation during a certain period (e.g. weeks, decades): these are labelled innovators.

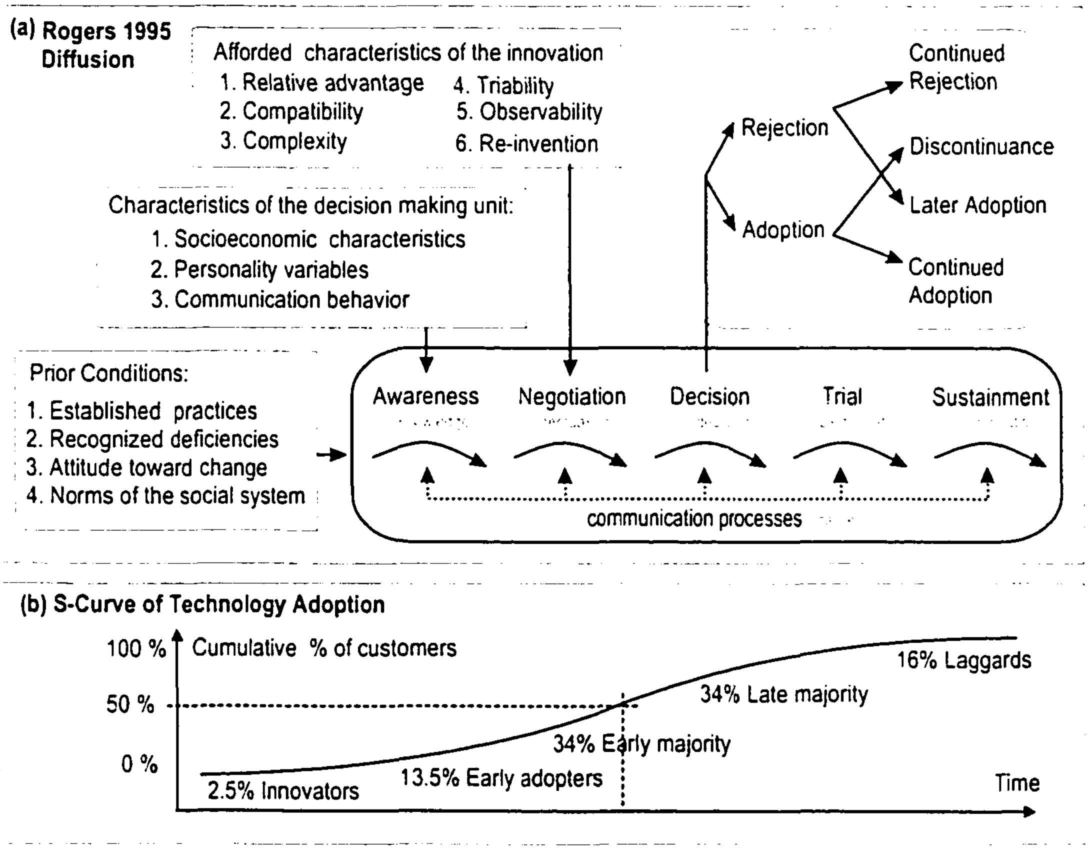

Figure 3.7: **Rogers' model of technology diffusion and the s-curve** (a) Diffusion as communication and cultural transformation, based on Rogers (1996) (b) s-curve of Technology Adoption

After this initial period, the curve begins to climb, as more individuals adopt the novelty in each period. At some point the number of new adopters starts to decrease, and the curve starts to level-off, eventually reaching an asymptote, which indicates the end of the diffusion process. The change ceases to be a novelty for the majority of the people. Rogers has classified groups of individuals as innovators, early adopters, early majority, late majority, and laggards.

The s-curve is product-centered, harnessing peoples' individuals differences and behaviors only by the time of adoption of a certain "innovation". It is the diffusion of the product itself that is measured, and not the knowledge about it. In this sense, although it describes the diffusion, it does not explain the motives behind its acceptance or rejection. I should remark that the s-curve is only one among many mechanisms that Rogers used to study diffusion. According to him, the rationale behind the adoption and the rate of adoption is contingent on (a) the perceived *relative advantage* of a innovation in comparison to the one it is to supercede, (b) the perceived *compatibility* with the existing practices, past experiences, and demanded requirements, (c) its perceived *complexity*, or the implied complexity associated with its learning and deployment, (d) the associated *triability*, that is "the degree of which it can be experimented with on a limited basis", and (e) the afforded *observability*, or how visible its results are to others who have not adopted it.

Across models of organizations there are several frameworks that model facets other than the product one. Recently, diffusion research become popular among technologists due to the large number of unsuccessful endeavors found among "high-tech" companies. In HCI, Donald A. Norman (1998) makes reference to diffusion research in order to analyze why products fail. Norman discussed the work of two authors: (a) Geoffrey A. Moore (Moore, 1991, 1995), who explored how to market and sell technology goods to mainstream customers [23], and (b) Clayton Christensen Christensen (1997a), who explores how large companies fail exactly because they disregard deviant practices and products by apparently doing everything "right".

Moore, for example, used Roger's categories of technology adopters to propose how to market and sell high-tech products. Moore modified a small part of Rogers's framework in order to explore a period across the life span of a product he called "the chasm". Moore's objective restated to HCI and Informatics the crucial importance of what lies beyond their traditional disciplinary niches. Moore and Christensen's works are complementary.

Moore's work is focused on the inner details of the diffusion process. Taking Rogers' adopter categories as a starting point, but using a Bell shaped curve (see

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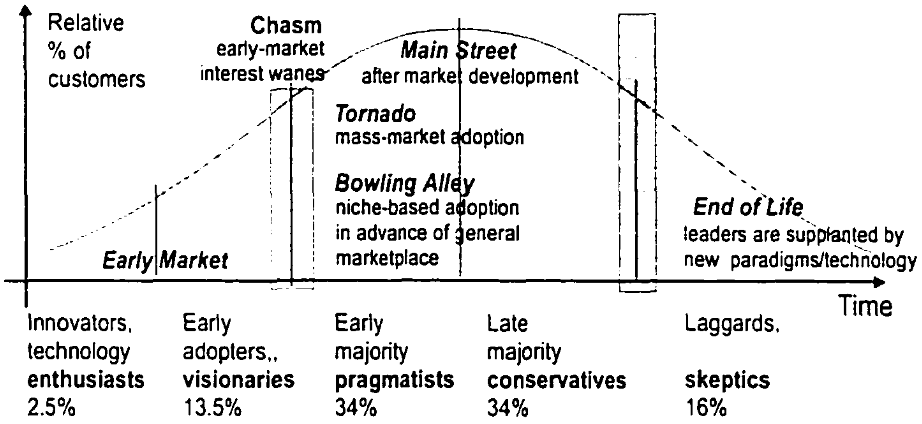
[23] See also Denning (1998, 2001) for a discussion of Moore's chasm in Informatics.



% of individuals in a social system to adopt an innovation	**characteristics**
Innovators, **2.5%**	Are venturesome and eager to try new ideas Have more years of formal education Have higher social status Have substantial financial resources Are able to cope with high degree of uncertainty Have contacts outside peer group May or may not be respected by peers
Early adopters, **13.5%**	Are respected by peers Are more integrated part of the local system Are opinion leaders - potential adopters look to them for advice and information Are change agents Play role models for other members of social system
Early majority **34%**	Deliberate before adopting new idea Adopt new ideas just before the average member of a system Interact frequently with peers Rarely hold positions of opinion leadership Provide interconnectedness in the system's interpersonal networks
Late majority **34%**	Approach innovations with caution and skepticism Adopt new ideas just after the member of a system Adoption may be due to economic necessity or peer pressure Are unwilling to risk scarce resources Uncertainty about innovation must be removed before adoption
Laggards, **16%**	Hold on to traditional values Offer resistance to innovations Are the last to adopt an innovation Are nearly isolated in the social networks of local system Are suspicious of innovations and agents of change

Moore 1991, 1995

Figure 3.8: **Moore's technology adoption lifecycle: characterizing the chasm**
Based on Moore (1991, 1995)

Figure 3.8). Moore explores a period of stagnation between the early adopters and the early majority, which he calls "the chasm", and a period of high rate of adoption, which he calls "the tornado".[24]

The attractiveness of Moore's model is its emphasis on the mainstream market, because it opens the closed professional perspective to elements usually found outside the professional's realm. Moore claims that high-technology companies have been wrongly focusing on the early market, mostly composed of their own peers, and not on the mainstream market, where the majority of possible adopters are. Although Moore recognized the value of the very late market (laggards), calling them skeptics, he emphatically discarded them, because they are not consumers. According to him, they block purchase and should be neutralized. See Figure 3.8 for a description of the main adopter's characteristics as developed by Rogers and adapted by Moore in his approach.

Rogers's approach to innovation diffusion as communication considered cultural factors as key to its processes. I understand that the slice that has been used by Moore, is too reduced and product oriented to foster human driven design. His short-term only for-profit strategy dehumanizes technology design, instead of humanizing it. The limitation of Moore's chasm comes to light once his model is used as a framework for reflection on issues associated with the digital divide. Within his perspective, laggards are marginalized and the excluded will remain excluded, because they are not even worthy of consideration.

Moore's work is focused on a single diffusion process. In contrast, Christensen (1997a) compares multiple diffusion processes. Christensen developed an alternative and broader study of diffusion. Christensen gives several examples of organizations that did everything right, everything in consonance with the tenets of technological "innovation", everything in accordance to their mainstream market, but still went

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[24] Moore's labels: (a) *Chasm*, the period in which early-market interest wanes (b) *Bowling Alley*, the niche-based adoption in advance of general marketplace, (c) *Tornado*, the period of mass-market adoption, (d) *Main Street*, the after-market development, and (e) *End of Life*, the period in which leaders are supplanted by new paradigms/technology.

bankrupt. Using information from the development of the rigid disk-drive industry. Christensen illustrated how products incorporating different technological solutions, sometimes with initial lower performance, have outgrown established ones in the long run. For that, Christensen differentiates technology development as either incremental or break-through (or disruptive). Christensen's work is complementary to Moore's because he provides a framework to compare the diffusion of multiple similar but competing innovations. Compared to Christensen, what Moore stresses as being the remedy for high-tech industries is what leads them to failure.

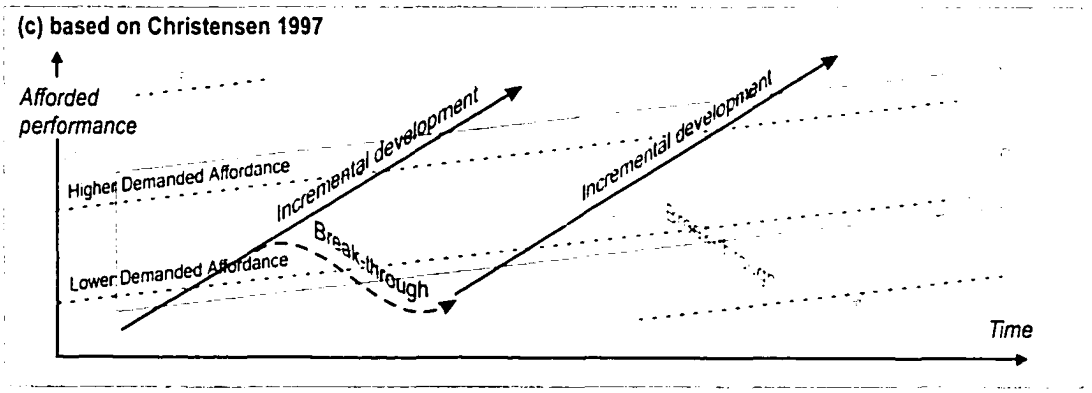

Figure 3.9: **Convergent and Divergent Diffusion curves:** based on Christensen (1997b)

Figure 3.9 illustrates the points of divergence and convergence of technology development in reference to Christensen (1997b)'s work.[25] More recently, Christensen has relabelled incremental and break-through as sustaining and disruptive, respectively (Christensen, 2000). I would rather call them convergent or divergent.

Christensen criticized most approaches for fostering a single perspective grounded on incremental convergent developmental paths, in disregard of divergent alternatives. Most successfully managed companies do incremental (sustainable and convergent) development. However, they feel completely unprepared to face the challenge and the menace of break-through development (disruptive or divergent). One-track incremental development stifles organizations.

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[25] See (Norman, 1998, chapter 11) for examples.

The menace of diverging practices is usually disregarded by large established companies because (a) they usually deliver outcomes with lower initial performance, and (b) they are apparently centered on a different application. This disguises the future competitive advantage of diverging tendencies. In other words, alternative paths usually look less promising due to the lower performance of their initial products and solutions, and because they usually address different user needs in conjunction with different technological solutions. But in the long term, they eventually overpass competing established and apparently healthy technologies. This only stresses that the only-for-profit short-term market-oriented perspective is in contradiction with the long-term development of its sustainability. For example, both the personal computer and graphic interfaces, were initially considered toys by large established companies.

In Figure 3.10(a) I extend Moore's model with the inclusion of two competing curves. I should remark, as Christensen has, that it is not easy to compare the performance of two technological products once they are tied to different applications (Christensen, 1997b, p 45). I developed Figure 3.10(a) and (b) assuming that two consecutive diffusion processes are associated with similar solutions that enable a comparison.[26] I depicted in Figure 3.10(b) the performance of two technologies developed for two overlapping activities, labelled A and B.[27] [28]

Norman's s-shaped curve does not depict the percent of adopters but the performance of a certain technological solution as a function of time. In Norman's diagram of the s-shaped performance evolution, he has added an acceptance threshold, clearly

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[26] The curves are conceptual and there are associated methodological problems that go well beyond the scope of this thesis (e.g. One curve would probably interfere in the other.). Most diffusion research measures the adoption of a unique product (Rogers and Agarwala-Rogers, 1976). The comparison of two products supporting similar activities, but not equal, demands information on how the product is being used, and not only if it has or not been adopted.

[27] The s-shape follows Christensen's illustration (Christensen, 1997b, p 45, figure 2.6), and Norman's extension of Christensen's work (Norman, 1998, p 35).

[28] Indeed, the s-shape curve used in innovation diffusion should span across the entire period of the bell curve. Norman does not explain why he shortened the curve, excluding the very late adopters (or laggards, skeptics, luddites) as Moore suggested.

demarcating a level of performance required by users. This implies that there is a point of transition after which a certain technology satisfies basic needs. The period before that is associated with the early adopters. In this initial period, the artifact dominates use. The period beyond the transition point is associated with the late adopters, and a certain technological solution is either "good enough" or is "too good". From this point on, the artifact is less intrusive, and the activity dominates the interaction, leaving a mediatory function for the artifact.

The use of a single threshold has its drawbacks. Firstly, it streams the adopter categories in only two groups, early and late adopters. This distorts the continuous nature of the diffusion process into a discrete one. Secondly, it filters out non-adopters, reifying the bias against those who have not adopted it, who have rejected it, or who have adopted and rejected it, for whatever reason.

In Figure 3.10(b) I have extended Norman's threshold to an interval threshold. Beneath and beyond the extended threshold point, there is no diffusion process. For example, the diffusion process may exclude segments of the population that have other priorities that do not allow them to risk the adoption of such a solution. This group includes both the population who cannot afford its adoption, and those for whom it is not culturally interesting to adopt it.

In Figures 3.9 and 3.10(b), I have chosen two particular thresholds to illustrate how a technology, B, which has a minimum threshold lower than the minimum threshold of an established technology, A, may eventually supercede it. Although depicted as a constant, the lower and the higher thresholds may vary across people and time. If the lower threshold is too high for a certain individual, the effort to incorporate it may be too demanding and too risky to be attempted. If the higher threshold is too high, the technology may not be appropriate to a certain activity at a certain time. It may be in the future, however, but that is the conundrum. The dilemma of the technologists is grounded on contradictory converging and diverging forces.[29] Although no process model will give the solution, it may facilitate his or her decision

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[29] The concept of "zone of proximal development" maps easily onto the interval threshold and is in consonance with the cultural, historical, and ecological approach adopted here (Zichenko, 1996).

on what to do. I have added this discussion on technology diffusion to illustrate the importance of diversity even in very business-oriented research. This is not the focus of this thesis, but a design process model should be comprehensive enough to encompass different strata of the interactions between people and technology, including organizational and social dimensions. Some of the consequences of technological development are its implications and consequences for the venues it intervenes.

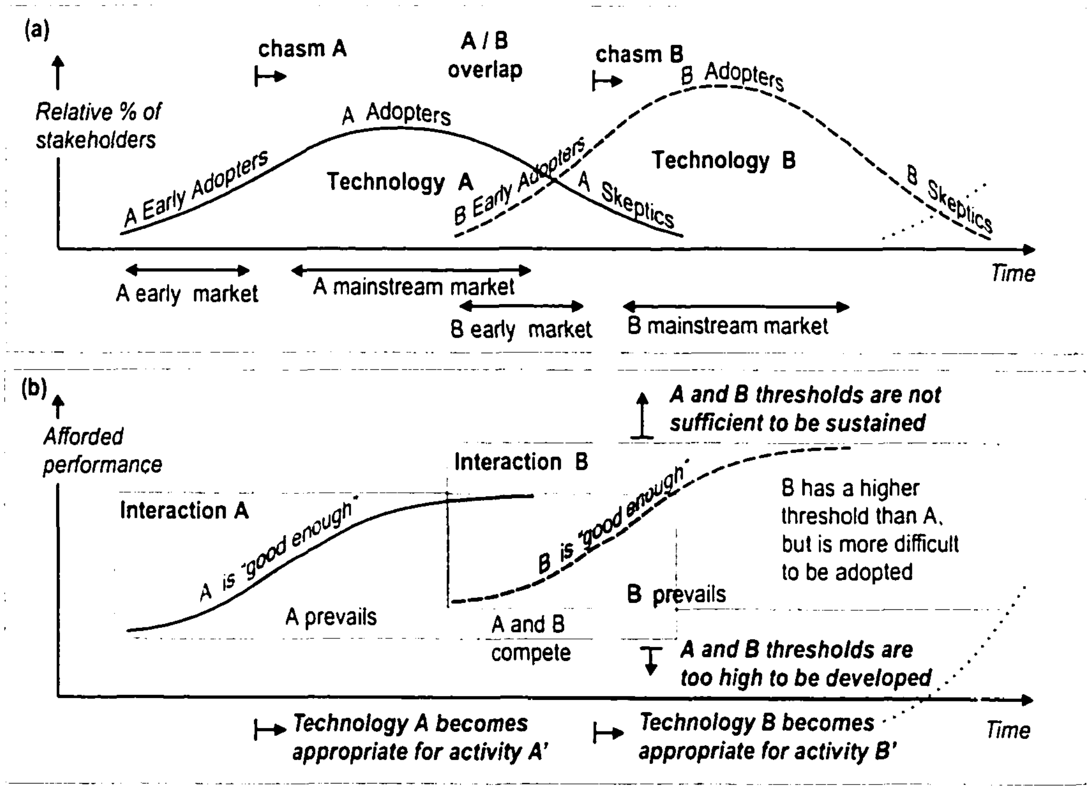

Figure 3.10: **Two technology diffusion curves**

Some remarks of the preceding sections include problems associated with the elitism found among HCI professionals, the possible manipulation of users by designers, and model in which very late adopters are not worthy of consideration.

My objective is to illustrate how models of communication can contribute to a better understanding of design processes in accordance with human and cultural perspectives. I also propose in the next sections a abstraction of spiral like models of software design processes which uses the Lorenz attractor as a pattern to visualize the recurrent patterns commonly found in such design processes. Then, I exemplify how traditional process models such as the waterfall model, the spiral model, and prototyping encompass only small parts of broader design processes, tending to straightjacket peoples' activities within their specialization and established social networks.

3.5 Models of Organizational Processes

Design process models usually prescribe a set of activities to be followed, sequentially or concurrently In general, design processes have as their outcome material deliverables or products. Some have tended toward process-centered perspectives by addressing different design activities but are still structured around a product-centered point of view. It is enough to ask what is the outcome of a process model, a material product or a learned practice.

The objective of this section is to present some organizational models that include other dimensions in their structure. I now proceed with the presentation of several organizational approaches that have addressed process with the aid of dimensions other than product-centered ones. Besides product, some of these approaches correlate product development with economical and cognitive issues, differentiating for example: new from old markets, tacit from explicit knowledge, subjective from objective practices, and cooperative from uncooperative behavior.

Examples include different strategies for diversification (Ansoff, 1957); different sociological paradigms in organizational analysis (Burrel and Morgan, 1979); different conflicting models (Thomas, 1976) cited in Morgan (1986); different learning styles (Kolb, 1985); discontinuities in product lifecycles (Moore, 1991, 1995, 1996); dynamics of innovation through knowledge management (Nonaka and Takeuchi, 1995, 1997); identification of social paradigms in information systems development (Hirschheim and Klein, 1989); use of critical social theory in information system cycles (Ngwenyama, 1991); multiple paradigms in Human-Computer Interaction (Kammersgaard, 1988); resource management cycles (Holling, 1993); conflict of interests in software system analysis (Boehm and Port, 1999); social issues in software architecture (Cockburn, 1996); social learning cycles in an information space (Boisot, 1998) and their application in disaster management (Smith and Dowell, 1999); ideal space for semiotic engineering (de Souza, 1993); and a semiotic space to explore cognitive dynamics in organizations (van Heusden and Jorna, 2001). I have chosen these particular models as examples for two reasons. Firstly, they point out the moment or period across the whole lifetime of an institution (or policy) at or through which it is clear for its stakeholders that the actual form of organization is no longer appropriate to the extent that it needs structural transformations. Secondly, they have been used to understand the dynamic changes in institutions, be they governmental (policy making) or commercial (organization management). If design is to be understood within broader contexts and longer lifespans, these models are important examples.

Several of these models encompass concepts that had been studied in communications and semiotic studies. The communication model developed by Saussure in 1915 is the foundation of a long list of structuralist theories in linguistics and anthropology (Saussure, 1983). It has the bidirectional dyad signifier and signified (often read as object and subject) as its keystone, but it also discards what is subjective and individual, and what is not consensual or different.

Several of these models dichotomize relations: between subjects and objects, between different levels of abstraction, between the individual and the group, between the new and the old, between the tacit and the explicit, between the cooperative and the uncooperative.

These models sometimes draw on organizational, social, cognitive, communicative, and semiotic theories, sometimes naively, at other times explanatorily, and at still others explicitly. The attempt to include both subjective and objective issues across process models recognizes that there are subjective elements.

Frege's unidirectional dyad composed of *sense* and *reference*, widely used in logic, is another example of a concept that demarcates and differentiates what is language from what is real. There is no sense without reference.

The examples that follow illustrate several attempts to make use of dichotomies and dyads to structure solutions that go beyond the isolated product, market, individual, interface style, etc. It is possible to say that these examples go beyond established boundaries, but not enough to be in consonance with a Peircean framework. This brings to the fore the different ways of structuring sign relations. In the next chapter I explore the structure of Peirce's triadic and decadic sign relations.

Across Informatics, awareness for subjective issues is an advancement but it is also a challenge. It is an advancement because it shows that Informatics as a whole is maturing as a discipline. It is a challenge because specialists in technology development have been mostly unaware of theories and models of communication that encompass meaning and interpretation. Although it is possible to find examples of visionary work that theoretically related these issues throughout the development of Informatics, only recently has it started to acquire a significant status.

The next two examples are in HCI and illustrate the inclusion of dyadic semiotic frameworks in HCI. Kammersgaard (1988) used the distinction between expression and content to differentiate types of interaction, and Hutchins et al. (1986) used the distinction between conversation and world to differentiate types of interface.

As illustrated in Figure 3.11(a), Kammersgaard (1988) visualized four different perspectives as sources of design in Human-Computer Interaction. The classification scheme he proposed explicitly differentiates an expression level and a contents level. To organize the columns he employed a human dimension that distinguishes the individual from the collective. With this structure Kammersgaard (1988) characterized four major perspectives in HCI: a tool perspective, a systems perspective, a media perspective, and a dialogue partner perspective. From the perspective of communication and semiotics, Kammersgaard make use of a structuralist conceptual distinction between subject and object, but goes beyond it with the introduction of the human dimension that differentiates the individual from the collective.

The second example is illustrated in Figure 3.11(b). It is restricted to an even narrower scope. In order to differentiate direct manipulation interfaces, Hutchins et al. organized the lines of the classification table according to users' modes of engagement with interfaces, which could be as a conversations or as models of the world

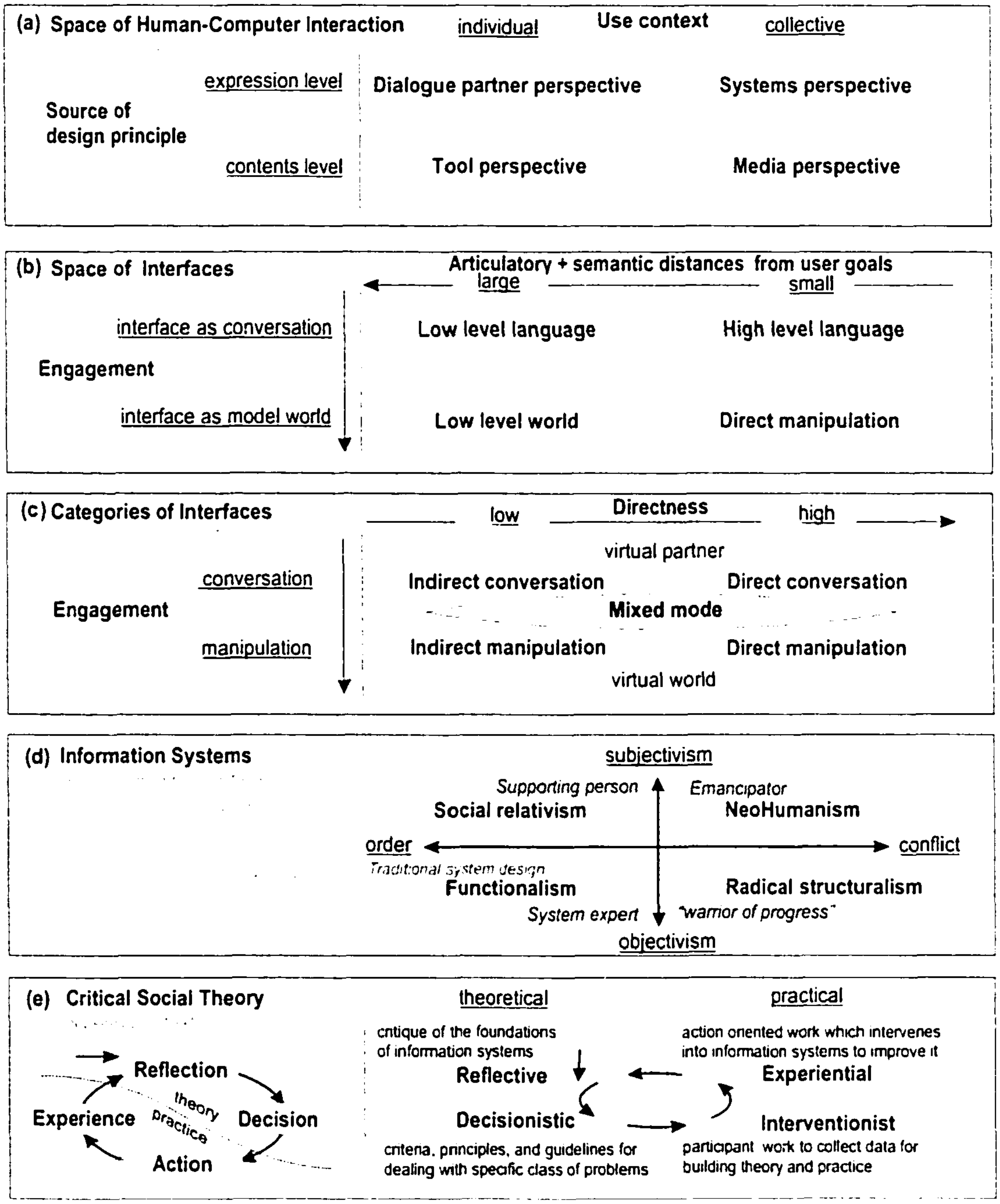

Figure 3.11: **Perspectives in HCI and Information Systems** (a) HCI sources of design principles (Kammersgaard, 1988, p 344) (b) Space of Interfaces (Hutchins et al., 1986, p 117) (c) Interface Categories (Frohlich, 1997, page 483) (d) Sociological paradigms in Information Systems Traditions (Hirschheim and Klein, 1989): based on Burrel and Morgan (1979), (e) use of Critical Social Theory in Information Systems (Ngwenyama, 1991, p 273)

(Hutchins et al., 1986, p 117). The second way of classifying interfaces was related to how far the interfaces were from the users' goals, which is related to semantic and articulatory distances as understood by the authors. Frohlich (1997) further refined Hutchins' model turning it continuous, as depicted in Figure 3.11(c).

At the organizational level I start with Ansoff's matrix proposed in 1957 depicted in Figure 3.12(a), which clearly extends the organizational conceptual space with a market-centered perspective. The development of new products may demand different strategies depending on the existence or absence of a market. Ansoff correlated new and existing products with new and existing markets. He derived four different strategies (Ansoff, 1957), including strategies for *product development*, for *market development*, for *market penetration*, and for *diversification*.

The two dimensions can be abstractly associated with segments of the human and the technological dimensions used in the HCI conceptual model. For example, Moore's (1991; 1995; 1996) chasm would be situated across two of Ansoff strategies, that is, new products initially developed for early markets become existing products in mainstream markets. The human and the technological could also be associated with the subjective and the objective elements, present in some of these examples, is also in some concepts of the sign, which is a key unit in some schools of semiotics.

Burrel and Morgan (1979) identified four different sociological paradigms used in organizational analysis: functionalism, radical humanism, radical structuralism, and interpretivism, with the aid of a grid similar to the one depicted in Figure 3.12(b). Burrel and Morgan structured their analysis through the correlation of what is subjective or objective (in one dimension) with what has consensus or conflict (in another dimension).

In Burrel and Morgan's model, subjectivity is found in those situations in which knowledge is understood as social practice. Objectivity is found when knowledge is understood as independent from human action and perception. Consensus tends toward sociology of regulation. Conflict tends toward sociology of radical change. The authors identified most organizational analysis as functionalist, in the sense that they foster a perspective of organizations as objective and consensual. Functionalist

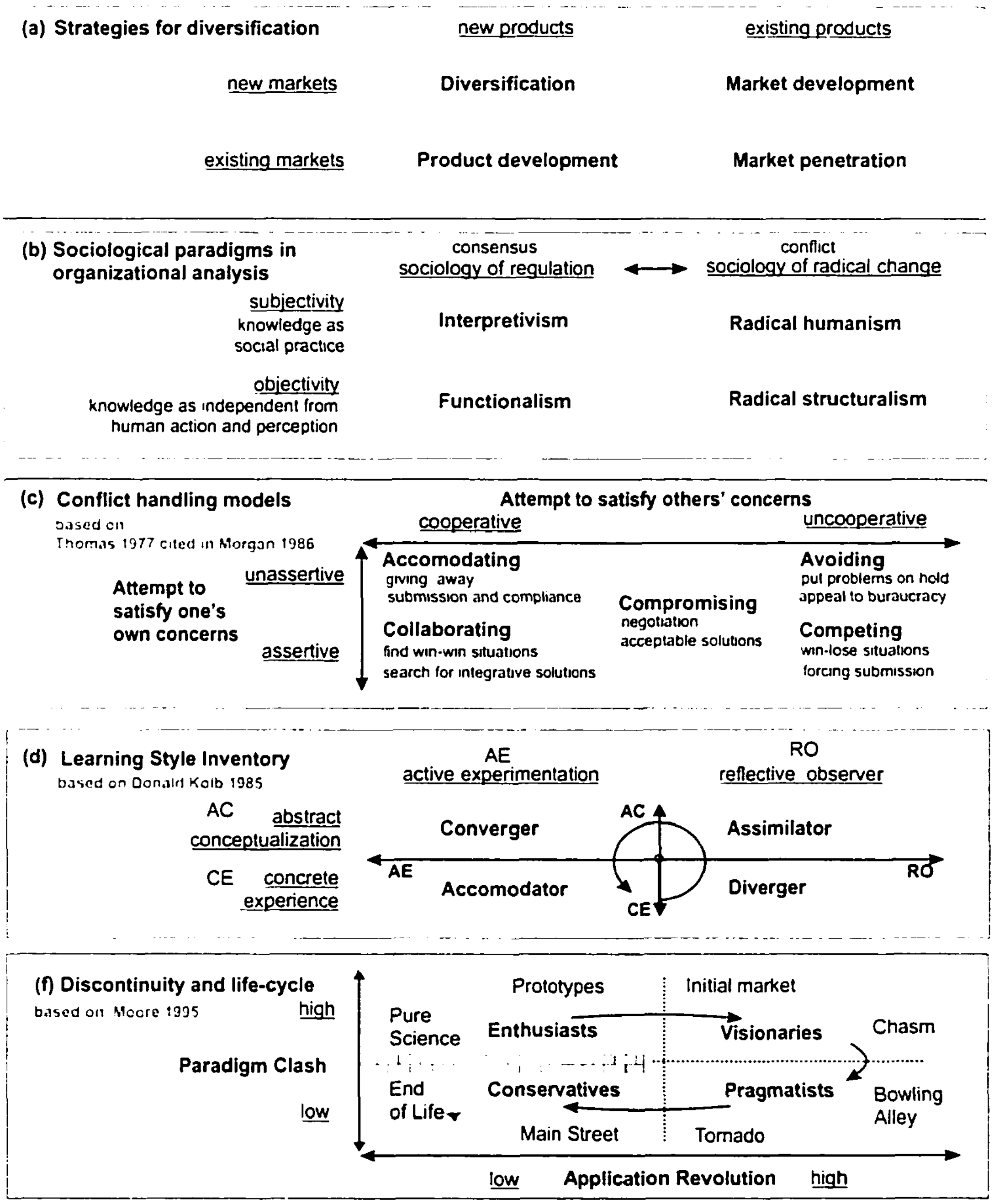

Figure 3.12: **Roles in organizations I** (a) Strategies for diversification (Ansoff, 1957) (b) Sociology in Organizational analysis (Burrel and Morgan, 1979) (c) Conflict handling models; based on Thomas (1976, p 900) cited in Morgan (1986, p 192) (d) Learning styles inventory; based on Kolb (1985) (e) Technology adoption lifecycle; based on (Moore, 1995, 1996, p 152)

approaches discard everything that is subjective or conflictual.

Product development and functionalism, both at the lower left corners of the two diagrams in Figure 3.12, have been the leading emphasis of Informatics. Using Burrel and Morgan's (1979)'s framework, Hirschheim and Klein (1989) classified traditional system design within an ordered, objective functionalist paradigm. See Figure 3.11(d) for an illustration. This only illustrates what I have already discussed in the preceding chapter about the focus on the limitations of the product-centered design processes traditionally sustained by the Informatics community. In product-centered world views, alterity and heterogeneity is not even acknowledged or recognized. There are only products, but no markets, no conflicts, no people, no abuses, no health problems, and no divides. These issues are beneath consideration, rarely considered, and often avoided. There are counter-examples, of course.

A second author who established a cross-disciplinary link between information systems and sociology is Ngwenyama (1991). Ngwenyama classified critical social theory within the Hirschheim and Klein (1989)'s neo-humanist paradigm and Burrel and Morgan's (1979) radical humanism. It stresses conflict and subjectivism, and fosters an emancipatory participative endeavor. Figure 3.11(e) illustrates the link between theory and practice across processes of reflection, decision, intervention, and experiment, establishing a circular dynamics.

For most managers, as Boehm (2000) described, project termination equals failure. It is taboo. Indeed, most activities carried on in software engineering, such as testing according to requirements, and in HCI, such as usability, could be classified as product-oriented and functional. There is performance, but no reflection on their implications and consequences.[30] It is not usually questioned that there is a set of stakeholders for whom the requirements and the testing are important and there are users who may not find a product usable. Looking from this different perspective, Software Engineering and HCI are mostly in accordance with the disciplinary scope traditionally maintained in Informatics. They are, however, at the disciplinary boundaries of Informatics, pointing to unexplored regions.

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[30] See Shön (1983) and Shön and Bennett (1996) for an understanding of the reflective practitioner.

This leads us to Figure 3.12(c). In management, for example, behavior is an important factor to consider. The assignment of tasks or positions to people is not done blind, and some frameworks have been developed to facilitate the handling of conflicts or failures.

Thomas (1976) (cited in Morgan, 1986, p 192) proposed a conceptual space structured on how people handle their own concerns in relation to how they handle others' concerns. People can be assertive or unassertive in handling their concerns, and cooperative or uncooperative in handling other's concerns. Instead of pigeonhole conflict handling models, Thomas proposed a continuous space to situate a certain approach, plotting on a surface collaboration, avoidance, competition, accommodation, and compromise (Thomas, 1976, p 900).[31]

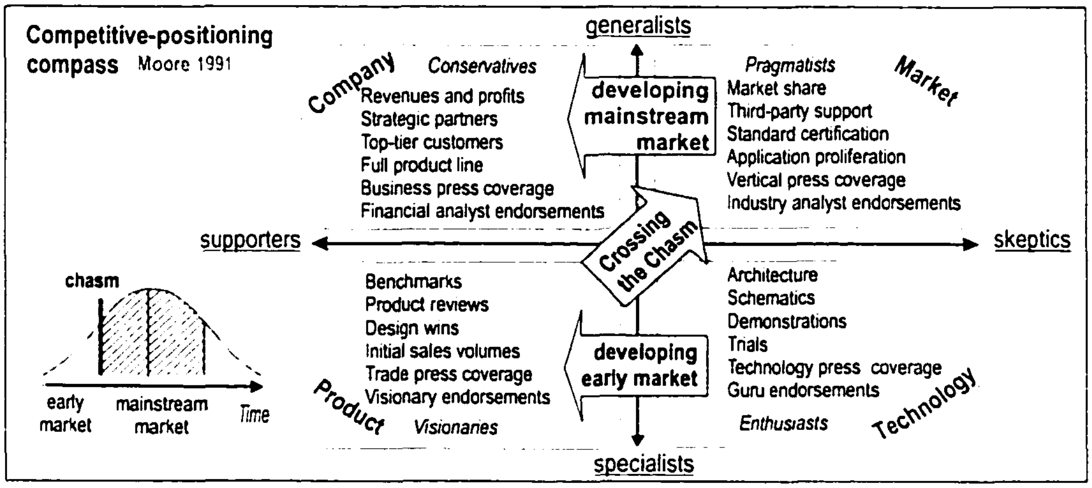

Figure 3.13: **Moore's Competitive Compass:** Based on (Moore, 1991, pp 141, 163)

At the individual level, Donald Kolb (1985) proposed a classification for learning styles, which is depicted in Figure 3.12(d). Kolb's model differentiates active experimentation from reflective observation and abstract conceptualization from concrete

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[31] I arranged Figure 3.12(c) in the same orientation as Figure 3.12(b), swapping consensus with cooperation and conflict with uncooperative. The parallel does not imply that people in Informatics tend to be cooperative and assertive. The answer is particular to each situation and depends both on who is addressing a conflict, and with whom. It is contingent on both individual and collective issues.

experience. According to Kolb's inventory of styles, people can be divergers, assimilators, convergers, or accomodators. The concept of style is not intended to stream a person to a single behavior, but rather to foster the development of other styles to complement the ones already developed. Kolb describes a process behind such learning styles, which involves several phases: (i) concrete experience is followed by (ii) reflective observation, which is followed by (iii) abstract conceptualization, which is followed by (iv) active experimentation. This exemplifies the concept of process within a conceptual space. The process is visualized as a sequence of actions across the conceptual space through the use of an oriented line, suggesting a trajectory. Most of the following examples use the same graphic resource.

Moore (1991) proposed two strategies to cross the chasm and used such a resource to visualize them. Figures 3.12(d) and 3.13 are based on Moore (1991) and Moore (1995), respectively, but I have redrawn them to facilitate the comparison. In the first one, which Moore called the "competitive positioning compass," he correlated the roles of people who are usually in the development phase of a product (either generalists or specialists), with the role of those who are at the deployment/use phase (either supporters or skeptics). See Figure 3.13. The process starts with enthusiasts, and it is sequentially followed by visionaries, pragmatists, and conservatives. The crossing of the chasm implies an organizational shift from a product-oriented to a market-oriented development (Moore, 1991, p 142).

In a second diagram, depicted at Figure 3.12(d), Moore correlated a high or low paradigm clash with a high and low application revolution. The similarity with Ansoff's grid is clear. The difference is that Moore suggested that the process should follow a specific linear order, and he explicitly drew a barrier across the enthusiastic inception of a product and its conservative end of life. I reiterate that Moore's objectives were to market and sell products to mainstream customers. A question that he did not answer is for how long. From that point on, he gave no graphic hints of what can happen to a technology, except showing that there is a wall blocking further development.

In the narrow time frame that Moore is addressing, it doesn't matter for how long, as long as it sells. Moore did not include "laggards" in his compass. However, Moore recognized that "laggards" could teach "high-tech" marketing what they were doing wrong, but he was not able to include their role in his model.[32]

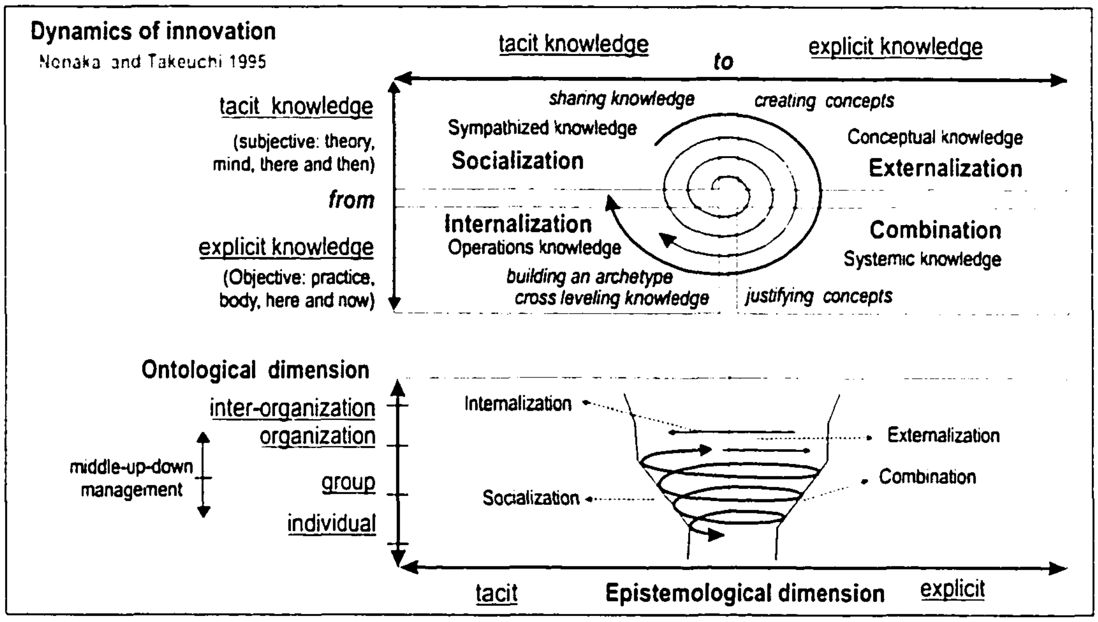

Figure 3.14: **Nonaka and Takeuchi's knowledge creation spiral:** Based on (Nonaka and Takeuchi, 1995, pp 80,82)

I shift now to an example in an area labelled knowledge management. In diagrams similar to the ones in Figure 3.14 Nonaka and Takeuchi (1995) proposed that the dynamics of innovation follows a helicoidal pattern composed of recurrent cycles of socialization, externalization, combination, and implementation. Nonaka and Takeuchi correlated the tacit and explicit epistemological dimension, drawing on Michael Polanyi's distinction in which a scale of the inter-organizational, organizational, collective, and individual organizes the ontological dimension. In their model, which was developed in the context of Japanese organizational cultures, knowledge

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[32] This tells a lot more about Moore's perspective than about the model itself. I return to a similar point discussing a model introduced by Holling in natural resource management, in which the role of those who resist the implementation of a policy are considered essential to its long-term sustainment.

diffusion processes start at middle management and diffuse up and down the company management hierarchy.[33]

In the above examples Thomas differentiated the unassertive from the assertive, Kolb differentiated the abstract from the concrete, and Moore differentiated the generalist (company-market) from the specialist (product-technology). Similarly, Nonaka and Takeuchi (1995) explored the dynamics of innovation between the tacit and explicit. While the work developed by Ansoff (1957), Burrel and Morgan (1979), and Thomas (1976) left open the possible combination of different aspects or dimensions of organizations and people, the work developed by Kolb (1985), Moore (1991, 1995, 1996), and Nonaka and Takeuchi (1995, 1997) delineated process sequences to guide action.

In this sense, Moore's process model is linear and is limited to a short period of a unique diffusion process. From one linear cycle to another, there is an insurmountable block. Moore's work is focused on the difficulties of overcoming differences, like the chasm, in order to sell more products to more people. Kolb (1985)'s model prescribes a circular pattern for process, which should be addressed in full to be balanced, despite individual strengths and weaknesses. Nonaka and Takeuchi (1995, 1997) add an ontological (human) dimension to the circular diffusion process, making it helicoidal, but their model remains limited to the organizational setting, ignoring the market.

Max H. Boisot (1995, 1998) proposed a model for learning in organizations in which social learning cycles flow through a three dimensional space labelled information-space. Boisot constructed his model based on the assumption that data is different from information, which is different from knowledge. Data is simply a "discernible difference between alternative states of a system". Information is data that " modifies the expectations or the conditional readiness of the observer." Knowledge is "the set of expectations that an observer holds with respect to an event." Boisot associates

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[33] See (Engeström, 1999b, p379) for commentaries and criticisms. Engeström argued that Nonaka and Takeuchi did not explain the leap from the spiral to the conceptual space and downplayed the role of small teams in Japanese companies.

(a) data with events in the world, (b) information with what is abstracted from data by an agent through perceptual and conceptual filters, and (c) knowledge with what is within the agent (Boisot, 1998, p 19-20). Boisot (1995, 1998) differentiated the codified from the uncodified, as illustrated in Figure 3.15.

Boisot only situates diffusion once data has been codified in an abstract form. Although depicted as a special dimension, diffusion ends up being restricted to a single part of the social learning cycle illustrated in Figure 3.15(a), which is composed of: (i) scanning, in which threats and opportunities are identified among fuzzy data; (ii) probelm-solving, in which structure is given to the identified fuzzy data through a process of codification; (iii) abstraction, in which the earlier developed structure is generalized to a wider range of situations; (iv) diffusion itself, in which the created insights are shared with the target population; (v) absorption; in which the codified insights are absorbed by the target population; and (vi) impacting, in which the abstract knowledge is finally embedded in concrete practices (Boisot, 1998, p 59-61). Boisot's learning curve flows in ordered, complex, and chaotic regions of his information space.

Boisot's model is an improvement but it applies a linear and passive perspective on human learning. There is minor space for concrete human-action. This position is in consonance with Boisot's world view in which the physical (source of labour power) is in opposition to the abstract (source of knowledge). Indeed he differentiated hunter-gather societies, form agricultural societies, from industrial societies based on the increasing amount of data they have, and on the more efficient systems these societies have developed. Boisot's Information-space is an important attempt to establish a framework for understanding learning in organizations. However, his disregard of the specialized literature about learning, knowledge, and communication, led him to re-invent the wheel with respect to organizations as cultural endeavors.[31]

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[31] Although Boisot makes reference to a wide set of references, he deliberately does not make reference to the literature in the human sciences in which the concept of information and knowledge has been widely discussed. Unfortunately, he ends up proposing concepts that have already been discussed in philosophy, psychology, semiotics, etc. For example, the concepts of data, information, and knowledge he proposed (Boisot, 1998, pp 19-20) can be seen as a particular case of Peirce's

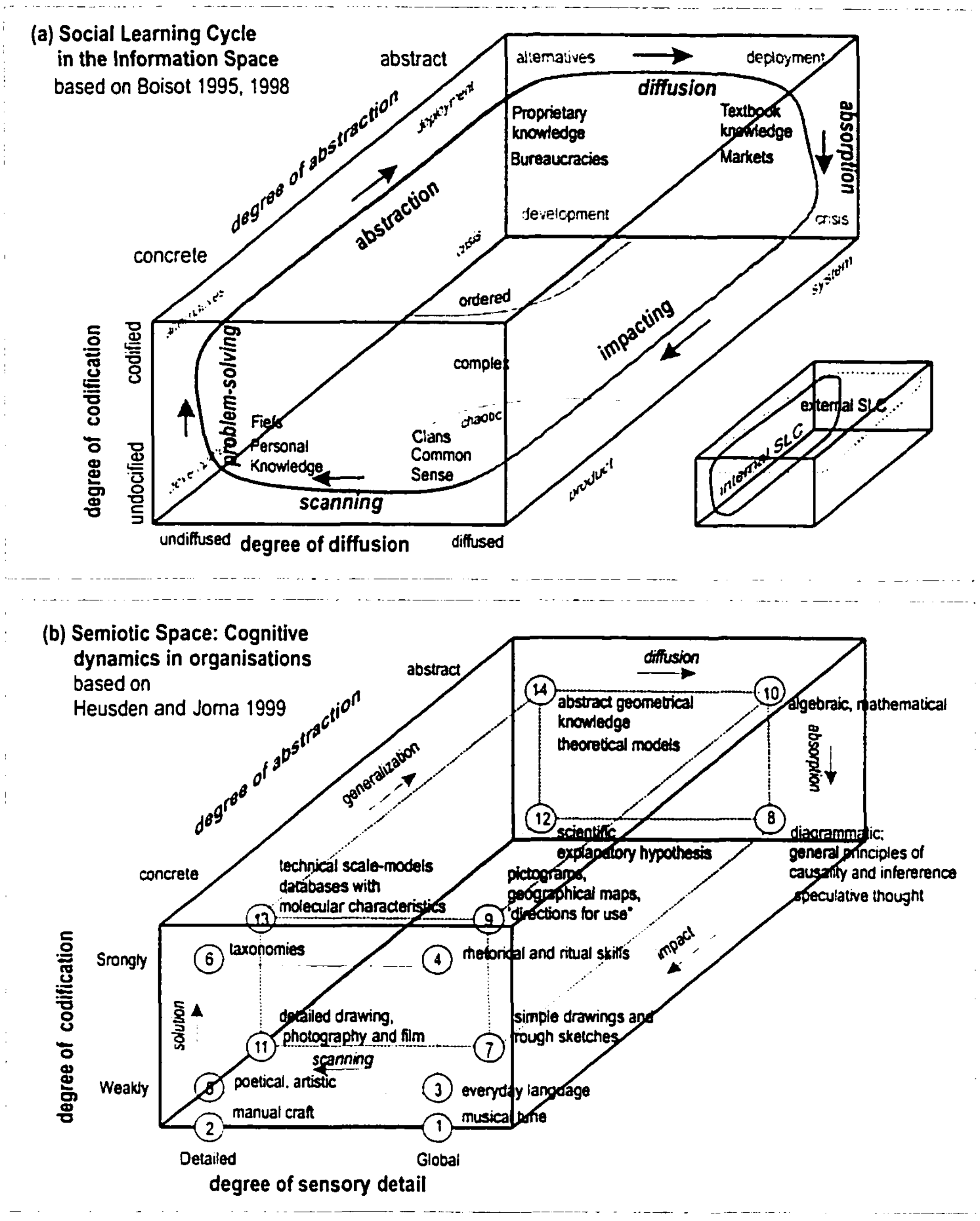

Figure 3.15: **Boisot's information space:** (a) Social learning curve based on Boisot (1998) (b) based on (van Heusden and Jorna, 2001)

For Boisot, a company or organization may develop different social learning cycles through which a focus on the internal and non-diffused cycle can be followed by a external and abstract cycle as illustrated in the lower right corner of Figure 3.15(a). An example in Information systems is based on the work of van Heusden and Jorna (2001) who explicitly discuss and criticize Boisot for misusing semiotic concepts. The authors, who participate in a project on Organizational Semiotics, substituted the diffusion dimension with one associated with the degree of sensory detail and proposed a more complex set of relationships among the cognitive and organizational processes. They described two types of sensory or tacit knowledge, four types of coded knowledge, and eight types of theoretical knowledge.[35]

Although Boisot did not mention the field of semiotics, two of the three dimensions he used are easily matched with Eco's framework used by de Souza to illustrate the conceptual space of Semiotic Engineering. See Figure 2.5 The mathematical distinction between types and tokens is used by Eco as the extremes of a scale associated with degrees of codification (ratio-facillis/ratio-difficilis). The degree in which a code is grammaticalized can be said parallel to the degree a code is structured.

The three dimensional models developed by de Souza (1993), Cockburn (1996), Boisot (1998), and van Heusden and Jorna (2001), described earlier, illustrate the multi-dimensionality of organizational spaces. The process models used to describe activities in these spaces, and in earlier two-dimensional examples, tend to be linear, even when depicted as circular. I proceed now with a model that suggests a richer dynamics developed in resource management.

Holling drew on adaptive dynamic cycles developed in the context of complex systems and explored them to discuss institutional cycles.[36] The flow of events in

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concept of firstness, secondness, and thirdness, discussed in the next chapter. In this sense Boisot's approach is interesting, but it could have been enriched if he had not explicitly downplayed the role of the humanities. See van Heusden and Jorna (2001) for criticisms.

[35] Although van Heusden and Jorna (2001) do not make extensive use of Peirce's semiotics, the model they developed have a close resemblance with the logic behind Peirce's categories of signs as I discuss in the next chapter.

[36] Michel Serres wrote extensively about the relation between communication and complex sys-

an ecosystem can be described through four flow of events cycles as depicted in Figure 3.16. The distance between the arrows intend to give an idea of the pace at which transformations occur. The closer the arrows, the faster the transformation is, as in the release and reorganization phases. The further the arrows, are the slower the transformation is, as in the exploitation and conservation phases.[37]

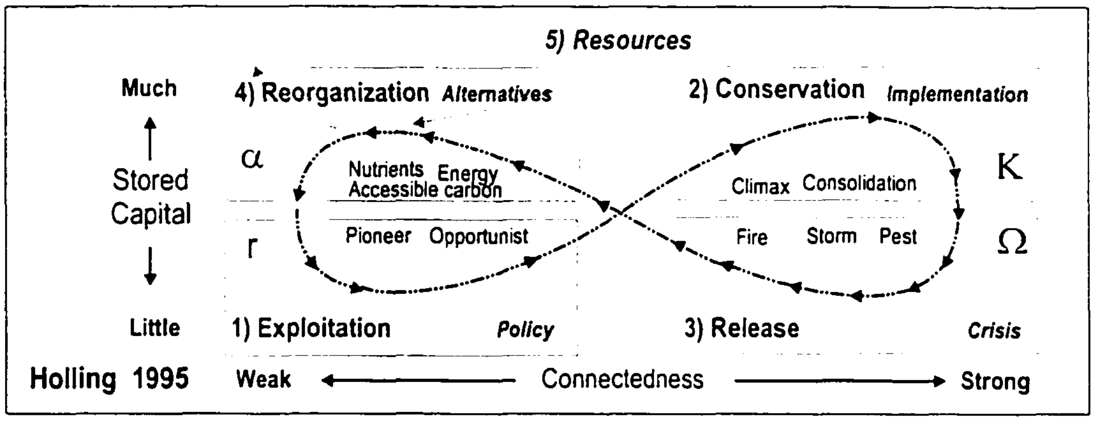

Figure 3.16: **Holling's four phase cycle** (Holling, 1995, p 22, redrawn)

Holling's four phase cycle reflects the transformations of two attributes of a dynamic systems: (a) amount of accumulated capital (nutrients, carbon) stored in dominant variables at the moment (vertical dimension) - and (b) the connectedness among the variables (horizontal dimension). The entrance/exit from the cycle depicted at the top-left corner suggests the transformations that lead to the emergence and senescence of a productive and organized system with an established dynamics (Holling, 1993, 1995).

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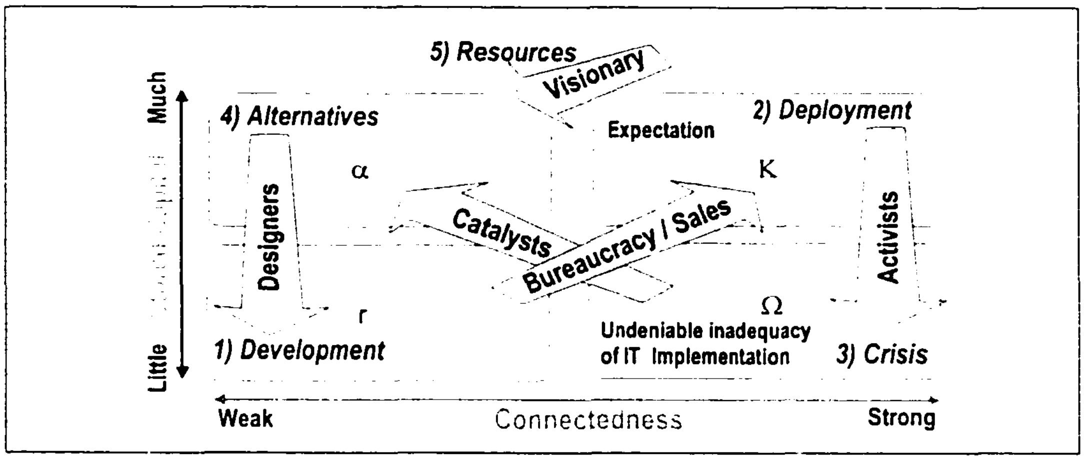
tems. See Serres and Latour (1995) and Serres (2001).

[37] Paul Klee used a similar diagram in his introductory art course at the Bauhaus. Klee distinguished three types of lines: active, medial, and passive. An active line freely moves, having a destination or not. Active lines became medial once they have described coherent forms. In case those forms where colored, the lines become passive, because color served as the active element (Whitford, 1984, p 114). An artifact could be understood freely, medial, and passive in relation to the activity it supports. I added this note to stress the metaphoric nature of these processes. I repeat, process models should not stifle professional practices, but foster a reflective critical attitude toward their appropriateness to different situations.



Attributes of Group Dominant at Different Phases of Adaptive, Four Phase Cycle

Phase of adaptative cycle	***5-4-5** (from resources to new alternatives)*	
Group Type	**Evolutionary / Visionary**	
Activity focus	Deep cooperative transformation	
Strategy	"Do as never before"	
Response to changes	Invention	
Time horizon	Distant future (multiple discontinuous time scales)	
Space horizon	Envisioning new bounds	
Nature of truth and reality	Creating new myths	
Phase of adaptative cycle	***4-1** (from alternatives to development)*	***2-3** (from deployment to crisis)*
Group Type	**Decision Makers / Strategist / Designer**	**Activists, Skeptics**
Activity focus	New cooperative learning	Insurgence
Strategy	"Invention tomorrow"	"Weathering the storm"
Response to changes	Reframing strategies	Conflict
Time horizon	Near future (multiple time scales)	Present (discontinuous time scale)
Space horizon	Creating new bounds	Destruction of old bounds
Nature of truth and reality	Reconfiguring myths	Competing explanations
Phase of adaptative cycle	***1-2** (from development to deployment)*	***3-4** (from crisis to alternatives)*
Group Type	**Bureaucracy / Sales**	**Catalysts / Brokers**
Activity focus	Self-serving	Unlearning
Strategy	"Do as before, but more"	"Unlearning yesterday"
Response to changes	No change	Shedding old behaviors
Time horizon	Time of office (linear time scale)	Time out (multiple time scales)
Space horizon	Building and holding bounds	Suspension of bounds
Nature of truth and reality	Constructed	Discovering what works

Figure 3.17: **Holling's key roles in institutional adaptive cycles** (Gunderson et al., 1995b, p 520-1, redrawn)

The implications of Holling (1993, 1995)'s model to natural resource management supported Gunderson et al. (1995b) in the identification of five main phases within institutional cycles. First of all, (i) resources must be available to start the process. Once it emerges, (ii) alternatives are searched, (iii) development is made, (iv) deployment takes place, (v) and a crisis is reached. The other mentioned circular models do not address periods of crisis.

Five main roles within the established dynamics link these four phases. (a) The role of visionaries is key, because they establish the cycle. This can be associated with Christensen (1997a) disruptive technologies. (b) Once the dynamics are established, decision-makers, depicted in Figure 3.17 as designers, broadly understood, filter the alternatives in order to start (c) the development phase. The phases associated with alternatives and development have a weak connectedness in the sense that they are not yet crystallized in the social structures across which the technology, or policy, would be diffused. (d) Bureaucracy plays a key role in taking what has been developed to deploy it. There is a gap, however, between what is deployed and people's expectations. Consequently there is a point at which it is undeniable that an implementation is inadequate, and (e) a crisis is reached. Activists play a key role in this phase, in which system breaks down. (f) If catalysts are able to reorganize the available resources and a new cycle starts, otherwise the dynamics vanish.

Forest management is a common example. Natural forests usually have natural fires. These small fires clean up the forest, breaking down the stored energy into valuable nutrients, which feed back to the forest. Large trees are usually not affected by small fires. However, if each fire is immediately extinguished, the collected amount of stored material puts at risk the whole forest. Frances Westley has related Holling's four phase adaptation cycle with cyclic patterns of organizational change as developed by Henry Minzberg. See (Westley, 1990, p 422), (Mintzberg, 1990), and Mintzberg and Waters (1985). Organizations need renewal. In other words, growth without renewal may imply unrecoverable breakdowns.

David K. Hurst (1995) also adapted Holling (1993, 1995)'s model to propose that controlled crises should be fostered across an organization in order to promote periodic renewal. His model has a seven phase cycle that traverses only three types of action (emergent, rational, and constrained.[38]

The catalysts could be the ones responsible for climbing Moore's insurmountable wall. Their role is important because it not only tracks the product down to the requirements of the application domain, but it also constrains the transformation process by a necessary inclusion of stakeholders through negotiation. It demands the recognition that the activity that technology is intended to support has always been there. For some people, this apparently tarnishes the artifact's and the developer's status.

As it will be discussed later, most models of design in Informatics, be they in Computing Science, HCI, or Software Engineering, have constellation of interests that do not include a focus on maintenance, breakdowns, disposal, contradiction and other related issues. Rather, these models focus on development. This is a serious pitfall. Information technology, intended to be used, often fails and without question gets outdated quite quickly. Furthermore, society does not know what to do with it when it is discarded.

Exceptions exist, and process models have been slowly considering longer life-spans across their concerns. However, they are not mainstream. For example Barry Boehm, who proposed the spiral software lifecycle, has stressed the importance of the human issues, including risk, in software process frameworks (Boehm and Ross, 1989). Recently, Boehm and Port (1999) explored the collision of interests across software systems development. Boehm and Port (1999) facilitated the understanding of MBASE (Model-based System Architecting and Software Engineering) with a framework involving three main principles: (a) the visualization of the relationships among the four main models incorporated into projects, each one focusing on specific

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[38] Hurst's model is more conservative than Holling's and conceptually biased in favor of developers who are creative and have choice (emergent action). Users are conservative and can create confusion when a crisis happens (constrained action). Hurst also translates the roles of bureaucracy and catalysts as, respectively, strategic management and charismatic leadership, classifying both as rational forms of action. This is in contradiction to Holling's model, in which catalysts are able to gather resources, but not necessarily rationally.

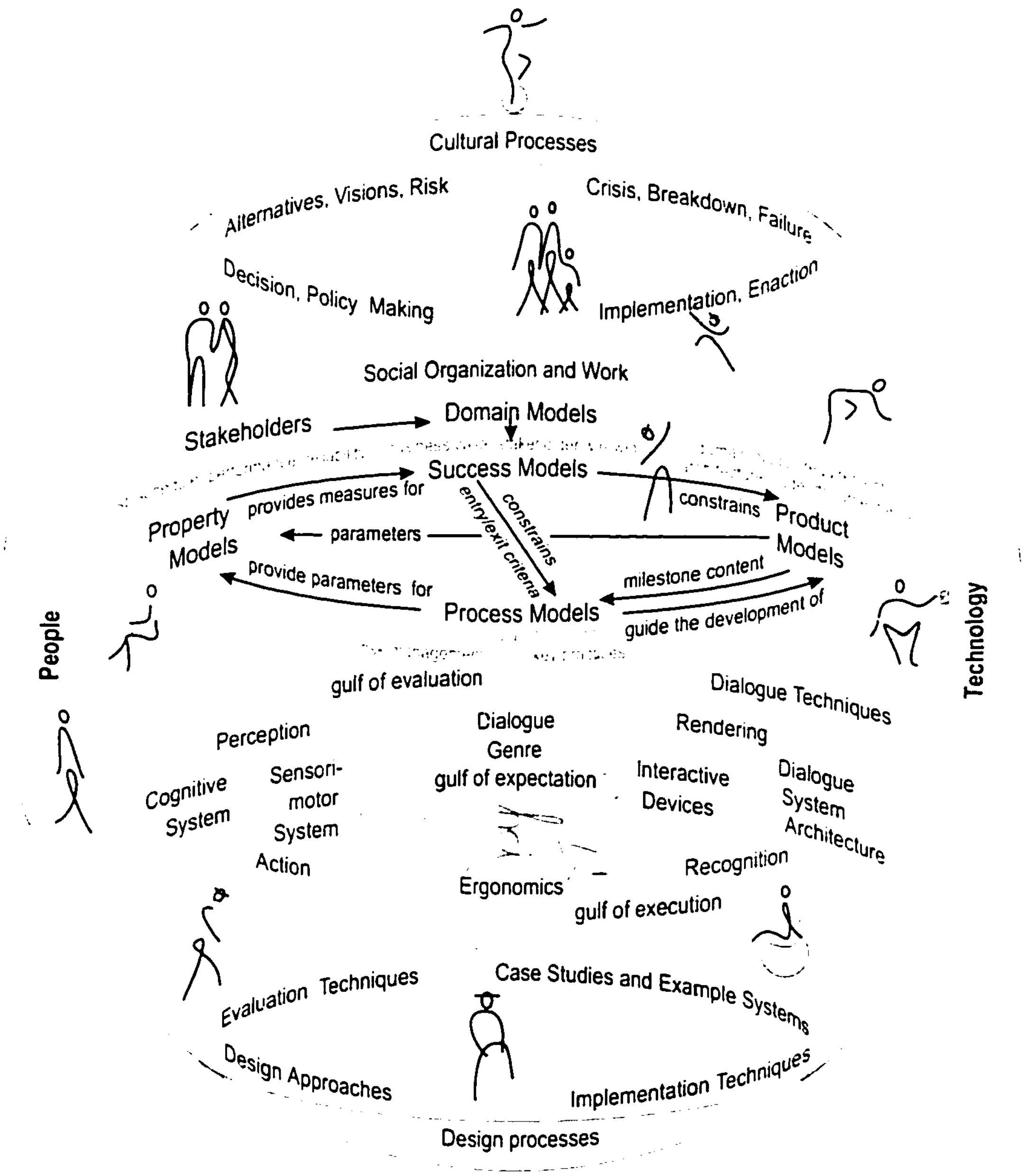

Figure 3.18: **MBASE model in relation to HCI conceptual space** Based also on (Boehm and Port, 1999, p 53)

attributes: (b) a visualization of how this model interacts and the associated interdependencies: and (c) a spiral like process anchored on management milestones based on Boehm and Ross (1989) and Boehm et al. (1998). which is an extension of the spiral model of software development. The four models include *process* and *product* models. and *success* and *property* models.[39]

In Figure 3.18 I established a parallel of the 2D HCI conceptual model introduced in Chapter 2 with Boehm and Port (1999)'s visualization of MBASE components and relations. I placed the relations between the models at the level of the organization in order to stress the managerial dimensions of Software Engineering. I placed each model in the region I found most appropriate according to what had been discussed earlier. The main objective of this diagram is to illustrate the complementary nature of frameworks developed in Informatics, in relation to HCI and software engineering.

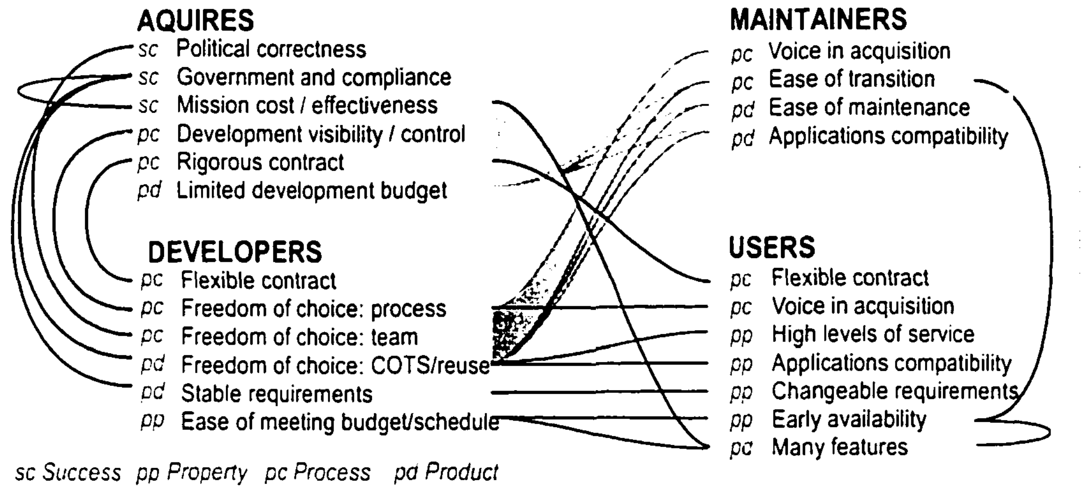

Figure 3.19: **Untangling Boehm's Software Model-Clash Spiderweb** See (Boehm et al., 2000, p 121) and Boehm and Port (1999)

Using MBASE as a starting point to analyze the contradictions among property, product, process, and success models. Boehm et al. (2000) illustrated a large set of contradictions found in the analysis of a commercial system. They described intricate relations as a model-clash spider-web (Boehm et al., 2000, p 121). Figure 3.19 shows

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[39] See also Boehm (1988) and Boehm and Hansen (2000).

an untangled version of their illustration. The Gordian-knot of the model-clash was untied with the aid of a scaffold developed by Holling (1993) in resource management and depicted in Figures 3.16 and 3.17.

In relation to the other process models presented above, Holling (1993, 1995)'s model is one of the most comprehensive. However, connectedness and stored capital is not clearly related to the technological, human, and interactive dimensions used to model Informatics and HCI. Later on, I propose to subdivide connectedness into the human and the technological dimensions, extending the 2D model into a 3D one. In the next section I present some similar models used in Informatics as frameworks to differentiate design processes and interactive artifacts.

3.6 Towards a Model for Design Processes

The fact that HCI and Informatics' subject matter grew beyond what is manageable in laboratory conditions or small projects brought to design activities a myriad of other factors that had restricted influence before. I include among them, issues related to testing, management, stakeholders' interests, and fieldwork. These issues, and other similar ones, some of which have been addressed in the examples in the preceding section, are deeply entwined across the social, historical, and ethical dimensions of any profession.

In the first two chapters of this thesis I introduced multidimensional conceptual model of Informatics. Initially, I discussed disciplinary boundaries of Informatics in order to complement its organization with a human-centered one, and in what followed, called for the need to consider people's activities, including communicative ones, as necessary to enlarge and deepen the understanding of Informatics. In this chapter, I have already discussed a set of models, mostly classificatory, in which several dimensions are used to describe organizations, and its processes. Some of these conceptual spaces are structured along frameworks that have a great deal in common with frameworks widely used in linguistic, communication, and semiotic studies.

The conceptual model of HCI introduced in Chapter 2 fuzzily delimits a division of labor in which intersecting disciplinary constellations characterize professional competencies and identities. Informatics and HCI disciplinary trajectories exemplify the fluidity of such constellations across history. With the aid of models of diffusion, communication, and interaction, I further exemplified the concept of cultural niche and the tendency of disciplinary isolation of some fields. This homogenizing tendency stifles organizations and disciplines, which end up fostering only converging practices, and discouraging diverging ones.

When I was working on the preceding section, I reflected upon the possible aggregation on a single model of design processes of both the conceptual model of HCI introduced in Chapter 2 and the dynamic patterns of organizational processes. I understood that the main difficulty was to maintain the convoluted nature of organizational processes while enabling both convergent and divergent trajectories. Process models are mostly prescriptive, in the sense that they suggest future actions. My interest, however, was to develop the foundations of a process model capable of describing how prescribed solutions can drift away from their original plan. Prescriptions are contingent on their historical situation. For example, the "prescription" of antibiotics for infections only work up to a certain point, because the bacteria may change. Similarly, the prescription of a certain technology only works until a certain moment, because people also may change. A process model that is able to describe these factors is more expressive than one that is not able to capture them.

As I already said, some of software process models prescribe linear, circular, spiral, and helicoidal recurrent patterns of activities. But the circular, when represented graphically, returns to the same place, and consequently does not show what has changed in an iteration, or cycle. The spiral and helicoidal process models diverge, but monotonically, having a pattern that is as restrictive as the liner one. For example, the leap from a 3D space to a linear loop or a helix turns what is plural and heterogeneous into what is singular and homogenous. [10]. The encroachment of one of deterministic prescriptions into a process model enacts future action to a degree that I was not

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[10] That was at the basis of Engeström's criticism to Nonaka and Takeuchi's model.

willing to accept. However, the solution I was looking for had at least to include similar patterns in order to be historically sound, but it also needed to go beyond them.

I found a compromise in a curve developed by Edward N. Lorenz (1963), an MIT meteorologist, commonly known as the Lorenz attractor and depicted in Figure 3.20. The use of the Lorenz attractor is a metaphoric resource similar to the use of circumference to delineate any circular process. It enables the illustration of two "spirals" within one in a continuous process of change. I have been always suspicious of quick references to complex systems to prescribe human behavior. I prefer to understand this application of the Lorenz curve as a scaffold to inform professional action, not as a individual developmental path.

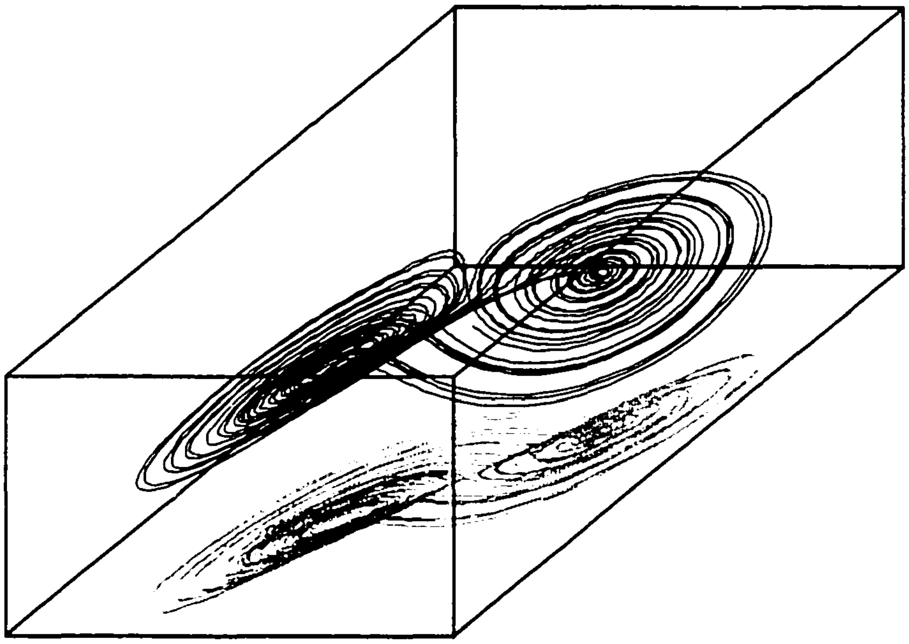

Figure 3.20: **Lorenz attractor**

Figure 3.20 four projections of a Lorenz attractor. Lorenz derive the equations that describe this attractor when he was modelling the behavior of rotating cylindrical rolls of heat conducting viscous fluids. The trajectory is still deterministic, but it is non-periodical. The x, y, and z coordinates depicted in Figure 3.20 are a function of a variable t, that represents the simulation time. $x(t)$ revolves around a point a number of times, establishing a disc pattern, and then flips to revolve around another point, forming a second disc. After a few loops revolving around this second point, it flips back to a trajectory that revolves around the initial point. This continues indefinitely (Falconer, 1990, p 186-7).

I propose a design process model with the aid of this curve, adapted to fit to a certain extent the HCI and organizational processes. The process model illustrated with the Lorenz attractor does not prescribe where to go, but it describes where it is possible to go. The Lorenz attractor exemplifies and effectively depicts the effect that small and infinitesimally different initial conditions can have in the future.

In explanations of traditional design processes it is not uncommon to find side comments remarking that such sub-processes can be shortcut or can evolve simultaneously. The use of the Lorenz attractor certainly brings contextual sensitivity to design process models, which generally tend to suppress divergent trajectories. The use of a Lorenz attractor is attractive because it illustrates that a small difference in opinion or action may have a significant impact in the long-term process. Indeed, considering that each stakeholder is different, the trajectory of a technology is far more complex than the analogy of the Lorenz attractor can capture. In this appropriation the two disks would correspond to niches usually associated with traditional design and traditional use. I now proceed with the construction of the model itself in relation to some models discussed earlier.

Holling's model had two dimensions, one associated with accumulated capital and a second one with connectedness. In order to construct a 3D design process model I supposed that machines and people are connected in distinct ways.[41] I took the second dimension (connectedness) and separated it into two: one related to the human and the other related to technology. I then associated capital with the interactive dimension.

I placed Holling's model in the 3D space. In Figure 3.21 I depicted the particular projection I have chosen to represent the Lorenz attractor in relation to the 3D

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[41] See Figures 2.17 and 2.9 in Chapter 2 for an explanation.

conceptual framework. I plotted Holling's four phase model proposed in the scope of natural resource management. The three projections are also represented in Figure 3.21.

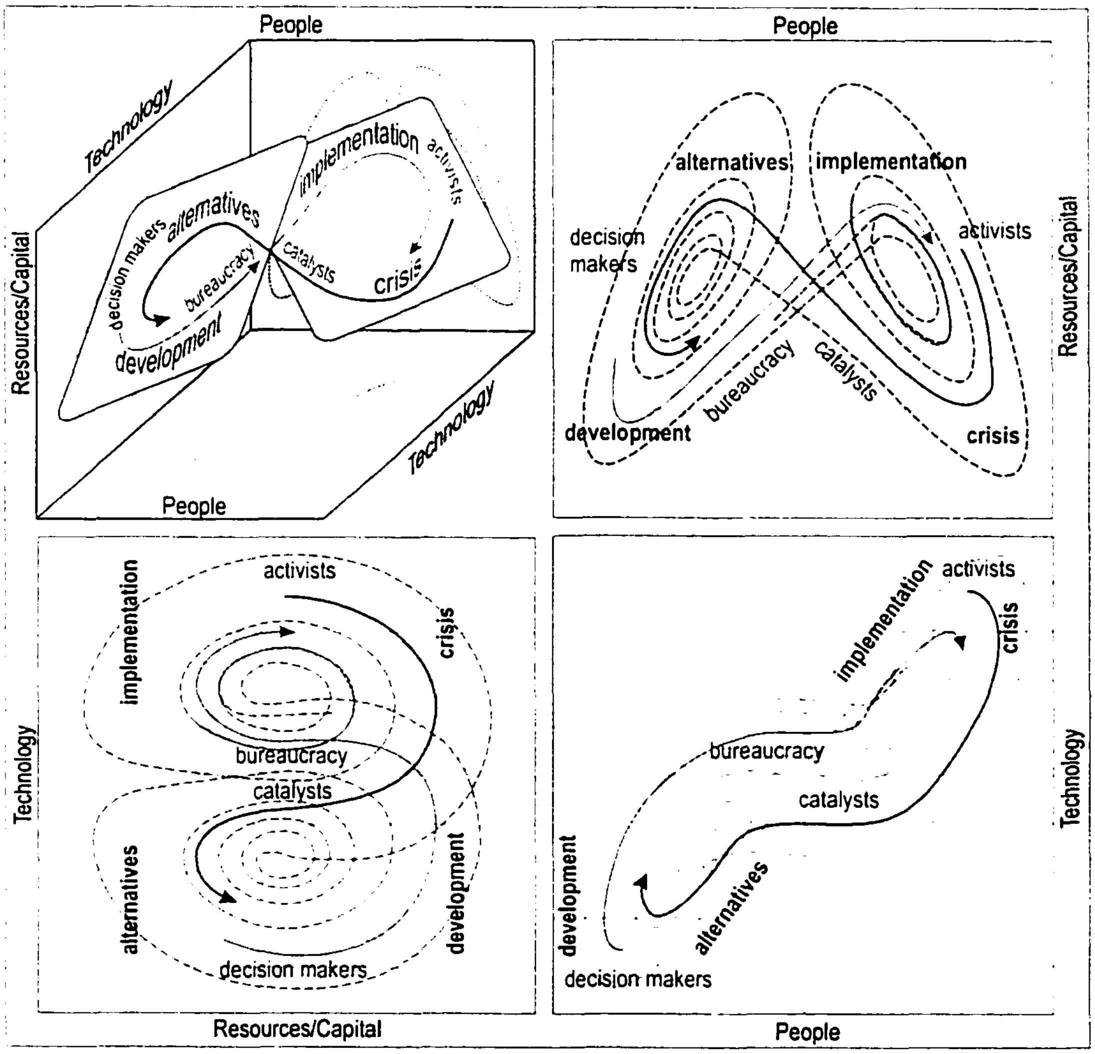

Figure 3.21: **Extension of Holling's model in three dimensions**

During the development phase, for example, the number of people does not vary much, but the technology increases. During the phase associated with the bureaucracy, it is the number of people that increases, but the technology remains relatively constant.I remark that Holling's 1993 four phase model is a local pattern used to describe particular ecological dynamics. Spaces describing broader life-scales and longer lifespans are usually described with the aid of several of these patterns (Gunderson et al., 1995b, p 520-1, redrawn), as previously depicted in Figure 3.16.

In a possible scenario, management may decide that either the market or the product is not ready for release, and the cycle may be shortened to a smaller cycle, remaining in one disc of the attractor. In another scenario, after development (first disc) it is possible to do a pilot study with actual customers, or to actually release a product for deployment, migrating to the second disc. Once in deployment both people and technology increase (second disc). At least that is the hope of those who developed it.

Once implemented, and in use, a crisis may be reached. During a crisis, both human and technological resources may drop. Users, and other stakeholders may be able to stop the breakdown process, but the human resources may continue to drop. At this point, people are either able to cope with the difficulties (remaining in the second disc), or differently specialized people re-evaluate (swapping back to the first disc) and sometimes rebuild the product, delivering newer version of it (returning to the second disc).

If the inadequacy of the product is undeniable, new alternatives need to be raised, and fewer and fewer decision-makers end up deciding which options should be developed (at the first disc). Once developed, human and technical resources are at the minimum. The future is uncertain, because the chosen changes may be not enough maintain the process indefinitely.

The choice of the two other projections of the Lorenz curve, which correlate technology versus resources, and people versus resources, were arbitrary, and I explain why. I assumed that variations in people's connectedness are usually in advance of variations on technology's connectedness. This is not always the case.[12]

I should remark, however, that this is still a model and the main rationale is to stress exactly every stakeholders' right of participation, freedom of choice, and ethical responsibility. The model should be taken as a reflective scaffold through which the

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[12] The model is in accordance with t he pace of the material variation depicted in Holling's model through sets.

limitations of existing models can be analyzed. Nevertheless, as it is it continues to be mostly a descriptive model.

But, everyday activities are deeply entwined in the professional identities of those who perform it, across their constellations of interest. It would be rather surprising if that were different. As is already happening, the disciplines of Informatics, and their members, are becoming increasingly aware of their cultural roles in society and across different societies.

In Informatics and HCI there are also a myriad of software process models, many more than it is possible to illustrate in a few examples. They vary in their emphasis on product, process, or human issues; on how they foster a perspective centered on designers or users; and on which phases of a product or technology lifetime they are limited to. In the remainder of this chapter, I analyze six process models with the aid of the proposed framework.

3.6.1 Some Archetypal Examples

My objective with the examples in this section is to illustrate the process model just introduced. I initially address the following software "lifecycles": (a) waterfall, (b) spiral, (c) win-win, (d) prototyping. The analysis is intended to illustrate the correspondence between the computer science cultural niche and its design practices. The four respective niches of these "lifecycles" encompass different regions of the conceptual space, and tend to enact distinct modes of stakeholder participation, which are related to the established division of labor. I conclude the section with models that explicitly show the recurrent nature of such processes: (e) the SEI-CMU IDEAL model developed for software engineering processes, and (f) Engeström (1999a)'s expansive learning cycle, developed in cultural and historical activity theory.

I structured each process model around activities focused on people, technology, and interactions. Several of these models do not encompass all of these dimensions. For example, an activity such as software testing usually does not include activities either related to hardware architecture or related to the evaluation of its usability.

Software testing has been a mostly product-centered individual activity.[13] Usability evaluation includes more people, having a distinct cultural niche, but it has been more limited to laboratory testing when compared to field studies, for example.

I start with the waterfall model because it is widely diffused in informatics. The waterfall model is commonly depicted as a series of boxes as in Figure 3.22. In Figure 3.22 I depict the waterfall model in a narrow and a broad version. The narrow version establishes the main steps to produce debugged code in response to a set of specifications prepared by someone else. It encompasses two levels of design: an architectural and a detailed one. Once a detailed design has been developed, this is passed to a programmer who codes and debugs the corresponding software. The waterfall model in its narrow version matches a division of labor in which the only role ascribed to some professionals in informatics is to acritically produce software. It is unidirectional and it emphasizes a short period of the whole process of technology development.

An assessment of the contribution of the waterfall model depends on its historical role. When interaction with computers did not allow a black-boxed engagement with them, people planned in advance what they expected the machine would be doing. "Pro-gramming", or advanced description, was not a structured activity, it was a laborious one, sometimes involving both harder and softer parts of the artifact in development.

Already in the 1960s several programming languages started to incorporate mechanisms that reflected concerns about the structure and the context of its developers. The practice of programming led to a structuring of its activities. Programming methodologies (and "lifecycles") appeared as patterns of activities to be followed and enforced in order to be successful in product delivery.

When Informatics achieved a level of development in which people could describe the behavior of computers on-the-fly, abstracting the hardware underneath, the professional attitude changed. What used to be pro-active planning involving hardware,

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[13] Extreme programming (XP) extended software programming to collective endeavors (Beck, 1998), but the community has been very reluctant in exploring it.

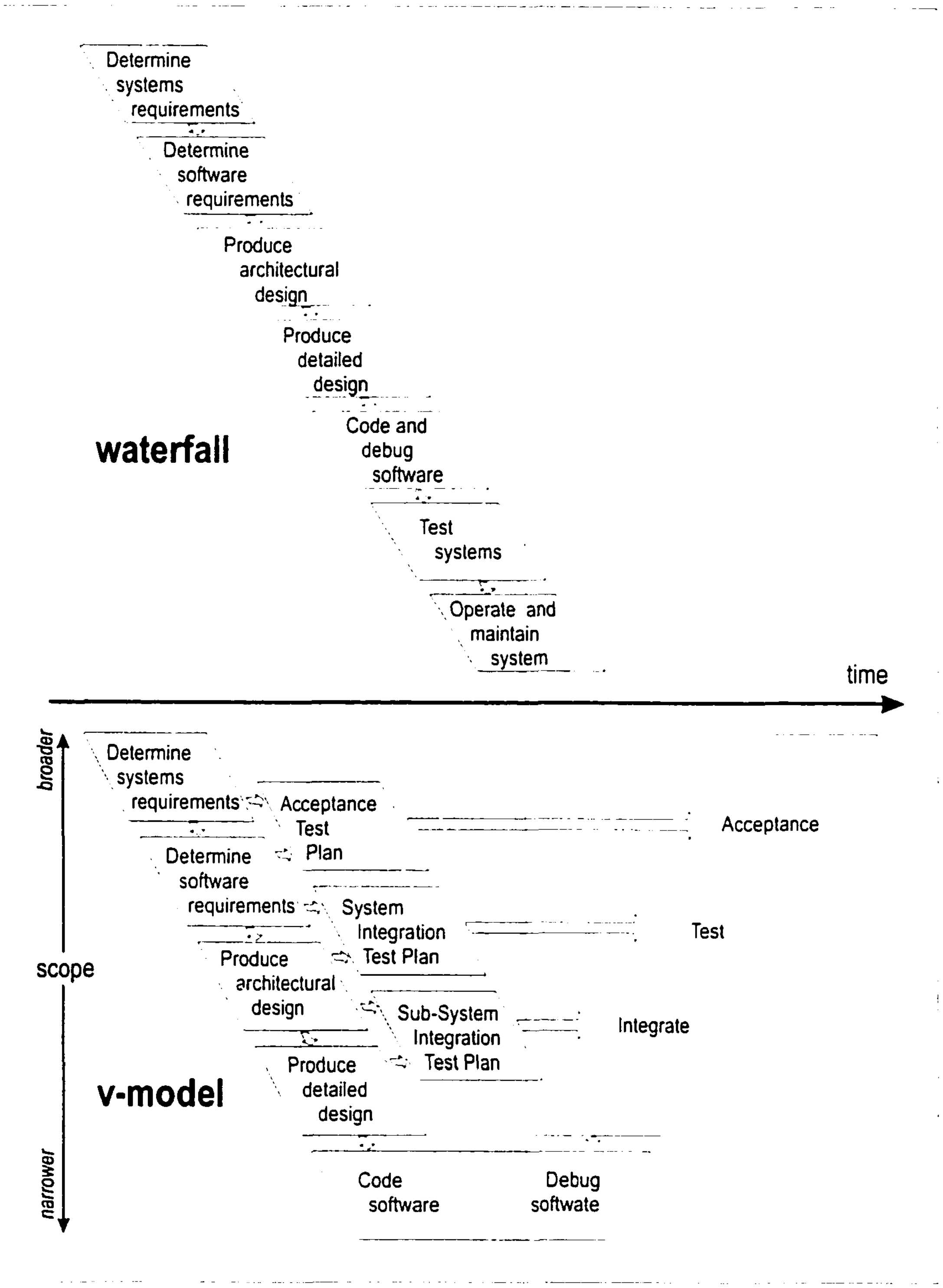

Figure 3.22: **Sequential design process models: waterfall and v-model**

software, and the application domain turned into a re-active task of coding and debugging software. This was in accordance with Informatics' broader division of labor which was sequentially separated phases for the specialized work of engineers, scientists, technologists, and end-users.

The waterfall model, with its simple, linear, unidirectional, cascade structure came as a response to excessively short-term development practices. Historically, the waterfall model represents an advancement toward the non-structured established practice. During this period, informatics' production line became very effective, and the interdependencies of hardware, software, application domain, and people were not put into question. Indeed, professionals took for granted their independence, otherwise they would have questioned their professional identity. This autonomy, however is only apparent. Concomitant with the increasing separation of education and working conditions from each other, professionals in different but traditional disciplines were and continue to be tightly coupled by an invisible and stable production chain (socioeconomic order). In accordance, programming practices consolidated as a non-reflective activity streamlined to the production of code and not to the appropriateness of its associated demands and consequences.

For example, the distinction between software development and software deployment is crucial between professionals in computer science and in information systems. For example, several process models in computer science do not include a phase related to software operation and maintenance. These models enact professional boundaries reifying the identities and practices of the involved communities. The structure has its drawbacks, however. In this organization once a product is delivered it leaves the enacted professional responsibility of developers and enters the enacted professional responsibility realm of deployers. In this framework once a product is accepted or delivered it also leaves the realm of professional practice. The chain is effective as long as there is a stable demand, which happens only as long as it continues to be advantageous for stakeholders to grant resources to that particular technology or product.

The realm of their professional responsibility usually goes only as far as the designers and deployers' world views permit. In product centered methodologies, it therefore excludes the user's realm. But even if this process model were further extended to be a prescriptive model, it would not free those who eventually subscribe to it from the responsibility for their actions. Indeed, it would made them more clear.

The professional order is stable only as long as there are resources to sustain it. This is not a characteristic found only in the Waterfall model, as I discuss in the sequence. The high pace and fast flux development of technology depends on very stable forms of professional organization. Simultaneously, it only supports this flux and pace because it has been structured in such a way. Both a high pace and a high flux are strongly prized in informatics, whose professional identities have the aura of being at the same time innovative and stable career paths, at least until recently.

This could be effective for a while, but not forever. The same organization and work flux that sustained the consolidation of Informatics is now hindering its development and renewal. As Informatics' cultural footprint enlarged, its consequences and responsibility also enlarged, demanding transformations in its professional organization. The resistance to new professional activities discussed in the first chapter is only one symptom of such a process.

Evidence of this process of renewal can be found in fields such as Software Engineering, which stressed what could come immediately before (requirements) and after coding (testing), or HCI (work analysis and usability testing). However, after thirty years, Software Engineers still struggle to diffuse processes related to software requirements and software testing. HCI is in the same situation. Both remain on the outskirts of the core competencies nurtured by the professional community. Only slowly, painstakingly, and reluctantly, traditional communities have shifted their focus to accommodate the demanded changes.

The waterfall model was heterodox in proposing a longer life-span for software development processes than the earlier established model which did not exist as a explicit process. It was orthodox, however, in strictly scheduling its production flow. The rise of software engineering, for example, demanded a broader view of design processes. Process models developed accordingly. For example, the waterfall model has been complemented once the production of software matured and the size of the projects grew. The inclusion of process phases denoting activities related to systems and software requirements filled the need of knowing, and also constraining, what should and what could be developed. The waterfall model was also appended with a phase of testing. In terms of Informatics' cultural ecology, software engineering areas such as requirements engineering, software requirements, and software testing co-developed accordingly, maintaining the established disciplinary and professional order, but complementing it with different perspectives.

In contrast to requirements and testing, operations and maintenance fall outside the usual established disciplinary niche of software development.[14] In consonance with this, the inclusion of a phase dedicated to the operation and the maintenance of the developed systems has not been as disseminated as requirements and testing. Maintenance and use are considered low-status activities, and they are mostly avoided by professionals.

The flow of deliverables and of power continues to be mainly downstream. Early decisions cannot be contested, even if they imply high costs later. A model that maintains the downstream flow of process development, but includes an earlier consideration of posterior consequences of current actions is the v-model depicted in Figure 3.22.

The v-model illustrated at the bottom of Figure 3.22 has an explicit connection between initial phases and later ones, linking requirements with acceptance, and design with test and integration. But the v-model usually ends abruptly once a product is accepted. Therefore, the importance of looking ahead is emphasized, so long as it does not break the limits of the established professional order.

Upstream counter-processes imply that roles and activities that are usually asso-

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[14] Although it has been proposed that processes in software engineering should include activities associated with installation, acceptance support, system operation, and user support, among others, they are not even present in most textbooks. See, for example, Bourque et al. (1998), who based their comparison on the number of textbooks and on the number of programs with required and optional courses in these areas.

ciated with the later phases of the waterfall model may influence earlier ones. Some diagrams include bi-directional processes, providing a structure for feedback and feed-forward. Both the waterfall and the v-model, in their unidirectional versions, do not contemplate the possibility of reaction, termination, or rejection.

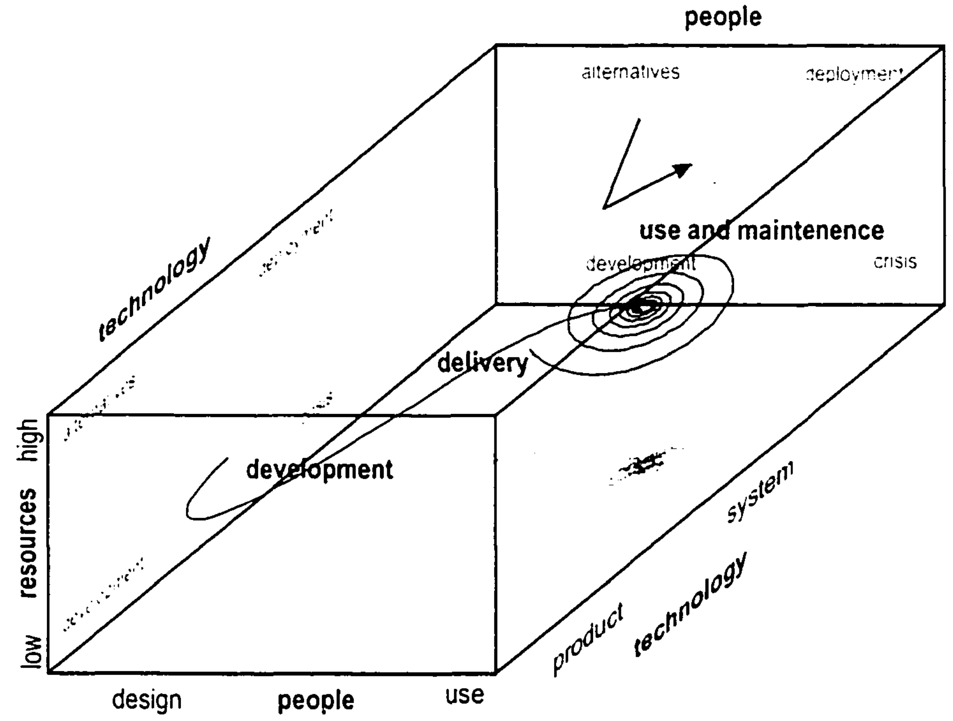

Figure 3.23: **Waterfall and v-model within HCI conceptual space**

I Figure 3.23 I depict the above linear models with the aid of the conceptual model introduced in Figure 3.20, the Lorenz attractor. Both the v-model and the waterfall model are usually limited to activities of development, understood narrowly, which are mostly situated at the lower, right octant of the enveloping parallelepiped, the realm of developers but not of users. I have included a spiral in Figure 3.23. This spiral is outside the realm usually encompassed by the waterfall and the v-model. It suggests that once a product is accepted, it is believed to acquire a life of its own, and other people will be responsible for it, be they "low-status" personnel, or easily blamed users. It is not by chance that professionals characterize users as incompetent in what they do, even though it is their area of expertise.

But models are simplifications, and actual development usually encompasses more than what is usually fostered in established academic and industrial settings. Actual work may be specialized, but specialization is effective only if it is complementary and is supported by an underlying structure. Some universities and industries are starting to develop mechanisms to foster interdisciplinary activities. Most theoretical models, however, do not even describe activities outside their professional realm, exactly because they are in the domain of others.

However, the dominant professional workflow established in Informatics does not support even already established practices of software production. For example, Jonathan Grudin identified three main scheduling genres associated with the activities of developers and users (Grudin, 1998, p 5). According to Grudin, developers are identified before users in *product development*; users are identified before developers in *contract development*; and both users and developers are identified simultaneously in *in-house and custom development*.

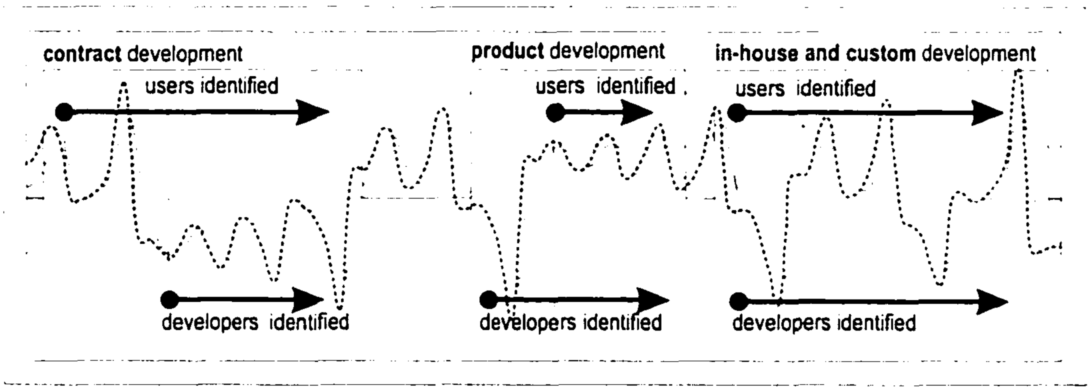

Figure 3.24: **Grudin's identification of users and developers:** based on Grudin (1998)

In Figure 3.24 I illustrate Grudin's relations between users and developers with the aid of two variables of a Lorenz attractor plotted as function of the simulation time. I have chosen this particular segment because it encompasses subsequent phases that match the three patterns described by Grudin, already mentioned above. The two curves represent the number of people and what has crystallized in both their practices and artifacts (technology). I have assumed that the number of stakeholders who are associated with development is usually smaller than the number of those who are associated with activities of use. The same can be said about the technology. Using Grudin's illustrations represented as black arrows, the three types of development are depicted sequentially, from left to right. I address the small oscillations in the sequence.

Barry Boehm developed an alternative family of process models characterized by cyclic iteration and the active management of risk was proposed during the late eighties.[15] Boehm developed two frameworks for spiral development, one that stressed its similarities with the traditional linear processes (Boehm, 1988), and a second one in which the role of multiple stakeholders have been emphasized. I depict my versions of both in Figure 3.25.[16] The former one is the most diffused across the professional community.

Boehm extended the original spiral to overcome its lack of guidance in determining objectives, constraints, and alternatives. The diagrams in Figure 3.25 explicitly show these deficiencies. The darker gray region on both diagrams of Figure 3.25 clearly show the absence of detail of such a region. The identification of system's stakeholders and their winning conditions points to negotiation processes to determine mutually satisfactory set of objectives, constraints, and alternatives.

Figure 3.26 illustrates Boehm's spirals in the graphical conceptual framework introduced earlier.[17] Boehm has recently addressed the nature of spiral development through a series of six invariant characteristics across the cycles, which include: (i) the

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[15] See Boehm (1988) and Boehm and Ross (1989). For a current appraisal of spiral development see Boehm et al. (1998), Boehm and Hansen (2000), and Hansen et al. (2000)

[16] The diagram at the bottom of Figure 3.25 resulted from a merging of Boehm (1988)'s original spiral model with Boehm et al. (1998)'s illustration of his Win-Win model. I should remark that the diagrams in Figure 3.25 do not do complete justice to the recent developments in spiral development. They are intended only to depict the different emphases of the two original spiral diagrams, as suggested by the authors themselves (Boehm and Hansen, 2000, p 23), and do not match perfectly.

[17] I strongly recommend the reader to view one of the many simulations or animation of the Lorenz attractors available on the WWW. The point in which the trajectory moves from one disk to the other is particularly illustrative in showing how contingent upon the circumstances is the actual development of a product.

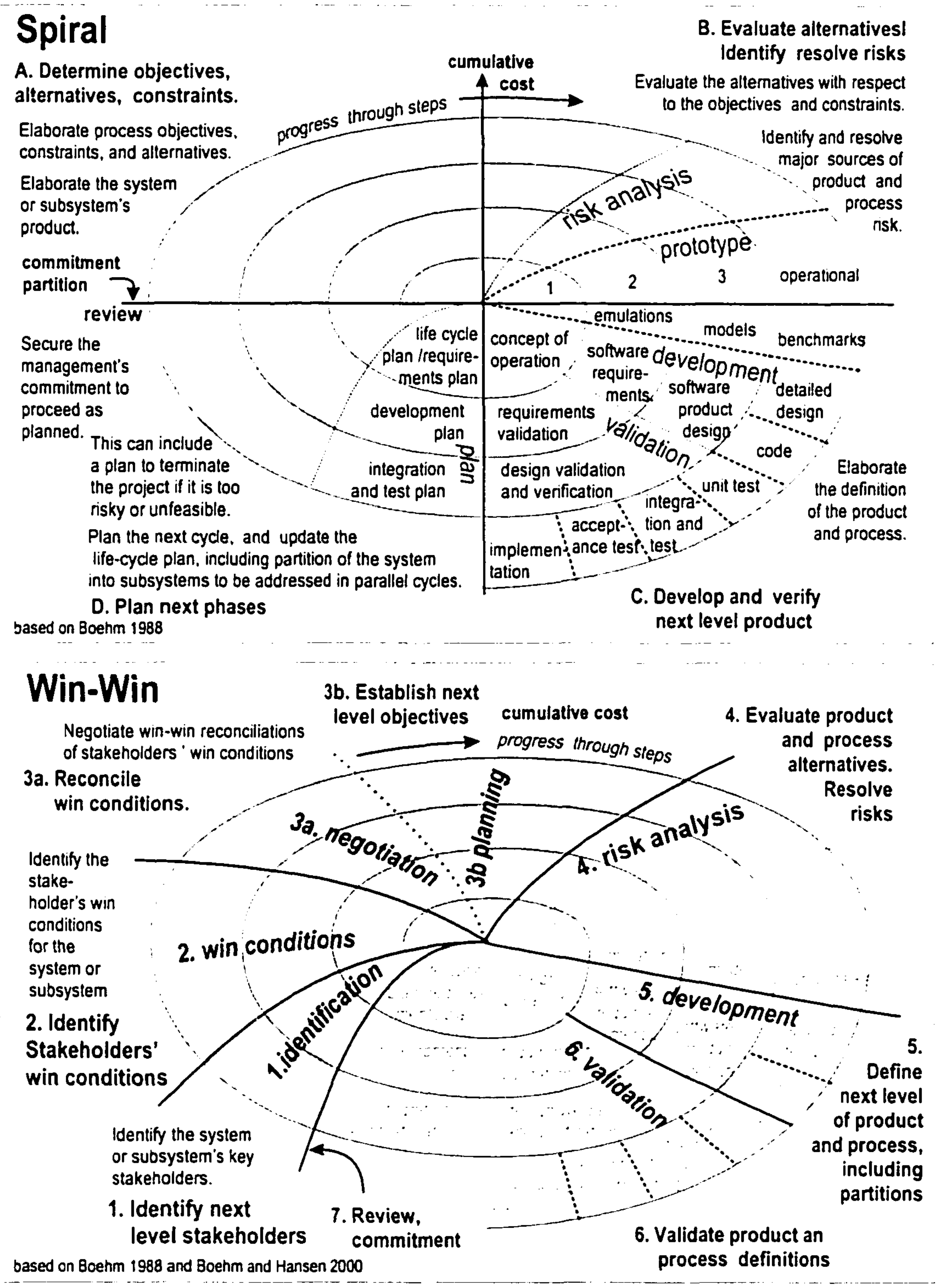

Figure 3.25: **Boehm's spiral design process models:** based on Boehm (1988) (Boehm and Hansen, 2000, p 23)

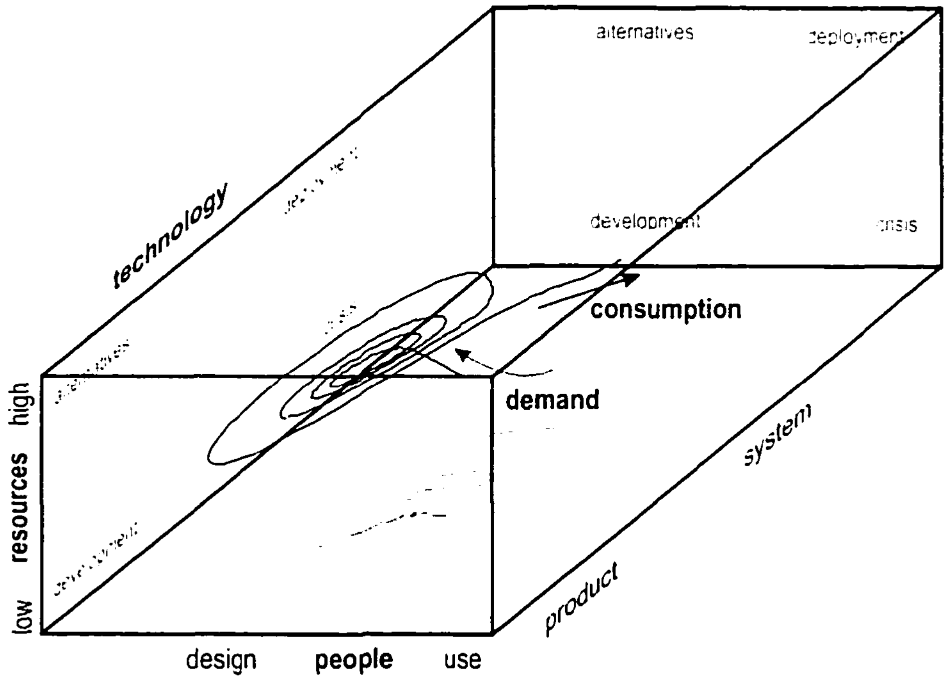

Figure 3.26: **Spiral development within HCI conceptual space**

concurrent rather than the sequential development of artifacts, (ii) the negotiation of stakeholders' related issues (which include critical objectives and constraints, alternatives, risk identification and resolution, stakeholder review, and commitment to proceed) (iii) the use of risk considerations to determine the emphasis of each cycle, (iv) the use of risk considerations to determine appropriate level of detail, (v) the pro-active management of commitments through different life-cycle milestones, and (vi) a corresponding emphasis on broader activities, including systemic and temporal considerations across artifact life-span (Boehm and Hansen, 2000, p 5).

These invariants indeed complement the contents of the spiral, guiding a broader view of technology development. In my understanding, Boehm's spiral would be best described by the double spiral pattern of the Lorenz curve. This leads us to processes of prototyping in which actual user participation influences a project's future.

In Figure 3.27 I depict a period of the Lorenz attractor in which the switch between discs is easily recognized. The two discs correspond to activities that revolve mainly around design and use, respectively. The process may switch back and forth between

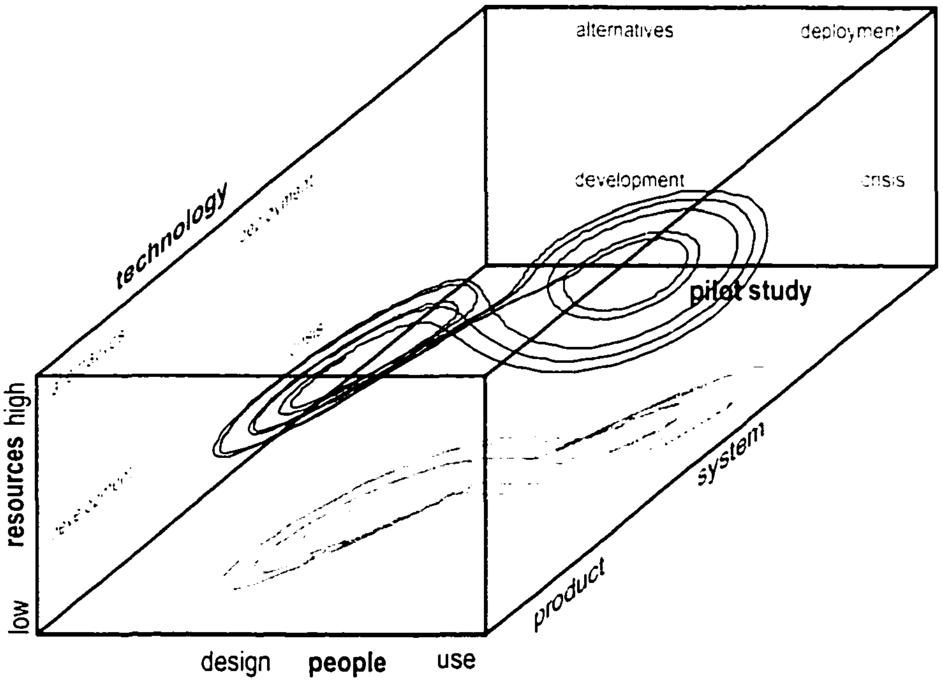

Figure 3.27: **Prototyping within HCI conceptual space**

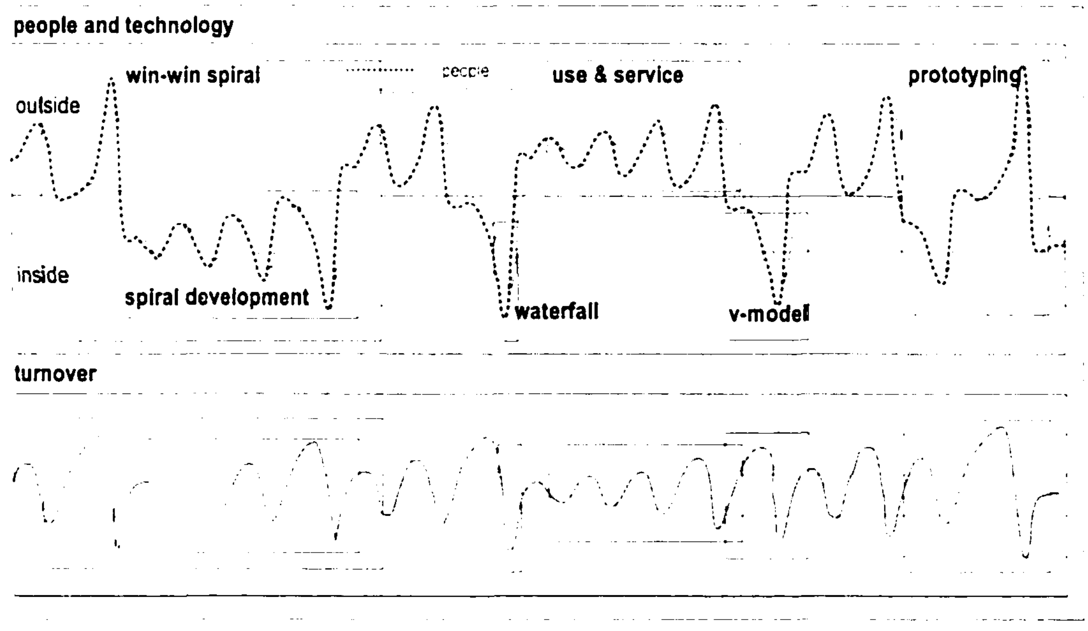

Figure 3.28: **Genres of development processes: several models in one**

cycles, but it also may stay in the user's realm for a while.

In the earlier chapter I used trajectories to describe HCI's and Informatics' historical development. My main purpose with these examples is to make it clear that the notions of disciplinary trajectories and design processes have a close connection with everyday professional practices. I concluded these four examples with another projection of the Lorenz curve in which the consecutive switch between discs illustrates their emphasis on developers or on users, as shown in Figure 3.28.

In two final examples I analyze models that encompassed richer conceptual structures, but that have been graphically represented as open circles. I chose one example in software engineering and one in the cognitive sciences.

The IDEAL model, depicted in Figure 3.29(a) and developed at the Software Engineering Institute at Carnegie Mellon University, is an approach to the software process improvement cycle CMU-SEI (1995, p 81 83).

IDEAL is an acronym which refers to five main phases: initiating, diagnosing, evaluating, acting, and learning (formerly leveraging). The emphasis of the IDEAL model, when mapped as a constellation of interests onto the Lorenz curve, is one of traditional design. Although *acting* includes both development and use, even at a finer level of detail, control remains in the designers' hands, leaving a passive role for the user, studied in a pilot test. At a finer level of detail, the constellation of activities is also concentrated at the developers side, with the exception of sub-processes related to setting context and pilot testing. The diagram shows, however, that the process is opened to the environment because it has phases of diagnosing and of learning.

I close with an example I took from cultural and historical psychology. Cultural Historical Activity Theory understands cognition and behavior as situated and deeply rooted in collectively artifact-mediated activity systems (Engeström, 1987). Engeström (1999b) studied recurrent patterns of knowledge creation in innovative learning in work teams. Engeström describes the expansive learning cycles in the following way:[18]

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[18] See also (Engeström, 1999b, p 383).

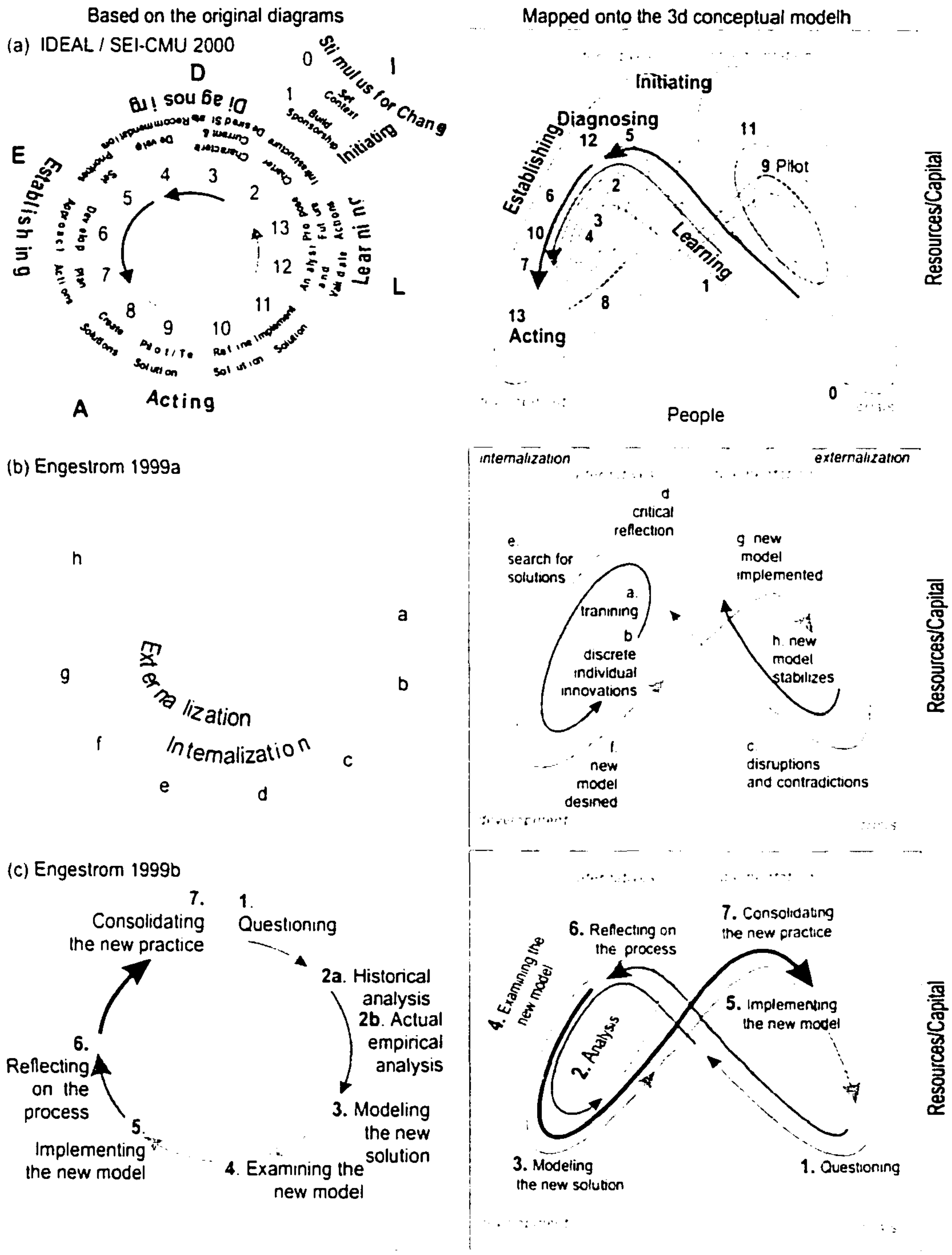

Figure 3.29: **Contrast between constellations of interests**(a) IDEAL model, adapted from CMU-SEI (1995, p 81–83, redrawn) (b) Expansive learning cycle, based on Engeström (1999a, p 33) (c) based on Engeström (1999b, p 384) (right) 3D model

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1998 Yrjö Engeström

Activity Theory and individual and social transformation (Engeström, 1999a, p 33)

[The] expansive cycle of an activity system begins with an almost exclusive emphasis on internalization, [(a)] on socializing and training novices to become competent members of an activity as it is routinely carried out. [(b)] Creative externalization occurs first in the form of discrete individual innovations. [(c)] As the disruptions and contradictions of the activity become more demanding, [(d)] internalization increasingly takes the form of critical-reflection – and externalization, [(e)] a search for solutions increases. [(f)] Externalization reaches its peak when a new model for the activity is designed and [(g)] implemented. [(h)] As the new model stabilizes itself, internalization of its inherent ways and means again becomes the dominant form of learning and development.

Engeström (1999b) criticized Nonaka and Takeuchi's (1995) leap from a matrix to a cycle as being too restrictive considering that it prescribes that the process start with socialization, but it leaves no space for debate or negotiation. Once his criticisms were placed, Engeström (1999b) proposed Activity Theory and Expansive Learning as alternative frameworks of explanation.

See the diagrams in Figure 3.29(b) and (c). They depict epistemic sequences of actions in expansive learning cycles, as proposed by Engeström, and the respective diagrams using the Lorernz attractor. The interplay between activities of internalization and externalization corresponds to the switch back and forth between what is internal to the individual and what is accessible to the community.

The left diagram in Figure 3.29(b) visualizes the proportion of externalization and internalization within the expansive cycle. In the right diagram, I visualized Engeström's general description of such a cycle. In it, it is possible to see that his approach encompasses the whole conceptual space, having a broader and more tightly interwoven constellation of interests than the IDEAL model one described above. On the right of Figure 3.29(c), I depict its respective trajectory.[19] The bottom one shows more clearly that "the expansive cycle begins with individual subjects questioning the

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[19] The differences between Engeström's illustrations are due to the fact that when in the (b) pictures I took the information from Engeström's text, in (c) I have used his own illustration.

accepted practice", which corresponds to the thinner arrow (1) at the left lower corner of the picture, "and it gradually expands into a collective movement or institution", which corresponds to the thicker arrow (7) crossing the whole picture.

In a broad perspective, engineers' users can be computer scientists, whose users can be information technologists, whose users can be information scientists, whose users can be final users, whose users can be the people who demand their services, and so on. As discussed in Chapter 2, professionals responsible for the early stages of HCI development look down on those who come after them. In this mode of thinking, decisions are never questioned, and if the solutions don't work users are often blamed.

The conceptual framework introduced in Chapters 1 and 2 is intended to map disciplinary links and disciplinary niches across Informatics, HCI, and beyond. Several 3D four phase cycles could be mapped onto it, describing different disciplinary niches in a 3D version of Figure 2.9.[50] The model visualized with the Lorenz attractor maps the activity between two of those professionals. Even if understood as a chain, the flow of activities is bidirectional.

Bidirectional disciplinary flow can have important consequences for professional practices. I hope that within such a perspective, the professional would become less prone to down play the applied, the alien, the customer. This can be exemplified with the role of software in engineering. At a certain point in the development of Computer (Electronic) Engineering the focus was hardware, not software. Software was a mere application of computers, which were the "hard stuff". Computing Science diverged from Engineering and developed its own discipline, developing depth in the software subject, but not in other subjects. Today the importance of software is not downplayed any more by engineers, to the point that they have become quite interested in it. In control systems this is known as feedback.

For more than a decade now, there has been renewed interest in Semiotics across informatics, a subject scantly explored as a motivation during the introduction of

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[50] This is in agrement with Holling's model. Examples in natural resource management can be found in Gunderson et al. (1995a).

high level programming languages.[51] This chapter close part I. Peircean Semiotics has been the scaffold I have used to structure these three initial chapters, but I have not explored in. A topic in Peircean Semiotics is indeed the subject of the next chapter, in Part II.

3.7 Summary and Final Remarks 3

Throughout this and the earlier chapters, I have stressed the importance of concepts related to agency, communication, and interaction to processes of design in HCI and Informatics. This chapter is intended to rescue and further develop some of the richness found in design processes, which are non-linear, parallel, and heterogeneous. From a Peircean-informed perspective, design processes would be necessarily bound with habit, but simultaneously would not be deterministic (Evolutionary Cosmology). However, most process models in Informatics, including the ones in HCI and Software Engineering, tend to be mostly deterministic in their prescriptions, and are restricted to the realm of developers in contraposition to the realm of users.

In this chapter I gave several examples of process models that use concepts similar to the ones developed in semiotics and communication studies. Dichotomies such as subject and object, the new and the old, internalization and externalization, the global and the detailed are examples.

When seen from the lens of design as communication, design lifecycles show clearly who interacts with whom across organizational processes. In the history of informatics models of design processes have been slowly including activities and stakeholders that have been previously abstracted away or simply ignored. Nevertheless, the systematic exclusion of some stakeholders or activities is deeply entrenched in the established cultural ecology. I discuss how processes of design and deployment are deeply related to the established cultural ecology of informatics. For example, those who come last in the usual sequence of technology production are usually ranked lower in terms of status. Based on several models of organizational processes I further complement the

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[51] See Zemanek (1966) for an early example.

HCI conceptual model with the notion of process. With these limitations in mind, a process model is proposed and discussed with the aid of the Lorenz attractor. I should remark that this process model is not a meta-model. However, it is expressive enough to encompass some existing models, thereby facilitating a graphic comparison between their scope. I discuss several process models in software engineering to illustrate its expressiveness.

Researchers in software engineering, usability studies, human-centered design, situated and mediated understanding of technology and cognition, among others, have recognized the limitations of formal approaches in technology design and evaluation and have attempted to go beyond them with different alternatives.

Several of the organizational and process models presented indeed make reference to concepts widely studied in semiotics. However, very few authors acknowledge that these concepts have been studied elsewhere. Their attempts are evidence of the need to close the crevasse between the sciences and the humanities, between professional activities related to information and computation, and between scholarship in communication and the practice of design.

With this chapter I close the discussion about the cultural ecology of Informatics and HCI. This has only been a start, however, in which I proposed a rough model of the disciplinary relations and the associated dynamics present across these fields. At several points across these three initial chapters I have pointed to the scant recognition that communication, broadly understood, has received both in HCI and in Informatics.

Michel Serres (1980) uses the metaphor of the Northwest Passage to describe the dangers of the ever changing path that links science with literature. I close these three initial chapters in the hope that the overview of the cultural ecology of Informatics gave the reader a feeling for its heterogeneity and for the challenge that its development will be.

In the next chapter I explore a tiny stretch of this intricate passage. I explore the structure of the sign, as proposed by Peirce, in what concerns the partial order of its elements. I do that with the aid of structures developed in the realm of the computing sciences, mostly in the field of data structures. The concept of the sign relation is the unity of analysis of Semiotics. For example, syntactics, semantics, and pragmatics have their origin in the organization of such a relation, but assume a different organization. The same can be said about data structures, which are fundamental structures in Informatics. The work reported in Chapter 4 is classified neither as computer science nor as semiotics as they are recognized today, but as both.

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Part II

Order in Peirce's Sign Relations and Derived Categories

Chapter 4

Sign Relations and Categories

> D'una città non godi le sette o le settantasette meraviglie,
> ma la riposte che dà a una tua domanda.
> Italo Calving, *Le Cittá Invisibility*

> I have neither desires nor fears, the Khan declared,
> and my dreams are composed either by my mind or by chance.
> Cities also believe they are the work of the mind or of chance,
> but neither the one nor the other suffices to hold up their walls.
> *You take delight not in a city's seven or seventy wonders,*
> *but in the answer it gives a question of yours.*
> Or the question it asks you, forcing you to answer,
> like Themes through the mouth of the Sphinx.
> Italo Calving, *Invisible Cities* [1]

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[1] Italo Calving, Invisible Cities, Harvest Books, William Weaver (Translator), 1986, added italics

4.1 HCI and Communication

The relatively recent awareness for a mutual influence between Informatics and communications has attracted the attention of some people across HCI and Informatics to disciplines that study language, communication, and interaction. In the remainder of this dissertation I increasingly narrow down the thesis' scope to such a niche. Across the HCI literature, several authors have already stressed the importance of communication in Informatics and in HCI. I quote some authors who expressed related thoughts in Table 4.1.

However it should not be forgotten that linguistics played a key role both in the introduction of computer languages and in its formalizations. The presence of a broad understanding of communication in Informatics slowly drifted from a key role in the sixties to the periphery of the discipline. It has remained in its outskirts until recently.

During the 1960s, the focus on syntax given in courses such as programming languages and compiler construction were complemented by topics with broader foci on languages and cognition in information retrieval and artificial intelligence. With the development of Informatics, once programming languages and compilers acquired a certain autonomy, the semantic and the pragmatic aspects of language were slowly abandoned by the involved community. The trajectory of phenomena related to communications, language, and interaction has followed the same pattern discussed here in Informatics and HCI. See Table 4.2 for a brief trajectory of language and communication related topics across the ACM curricula recommendations.

Noam Chomsky's contribution to the formalization of grammars has been key to the theoretical understanding of computers since the sixties. In 1956 he was working at the MIT Department of Modern Languages and at the Research Laboratory of Electronics. I have chosen Noam Chomsky's work to discuss how narrow are the concepts of languages in Informatics for two reasons. Firstly, Chomsky's theoretical scaffold has been partially discarded, and only a slice of his work in known in computer science. Secondly, in language studies, his whole work in linguistics has even

1993 Tom Dayton et al.

Skills Needed by User-Centered Design Practitioners in Real Software Development Environments

(Dayton et al., 1993, p 17)

[S]ocial, organizational, and communication skills are at least important as formal, technical knowledge, and are even necessary to ensure that the formal, technical knowledge is used effectively.

1993 Judith S. Olson et al. *Computer Supported Cooperative Work: Research issues for the 90s*

(Olson et al., 1993, p 93)

Research in CSCW contains everything in HCI plus:

There is a need for theories and models of the users. With group work, theories must additionally encompass the conversations among the participants, the roles they adopt, and the organizational setting which guides many group work actions implicitly, and the cultural practices.

1994 John Seely Brown and Paul Duguid

Borderline Issues. Social and Material Aspects of Design (Brown and Duguid, 1994, p 5)

We take design to be fundamentally a communicative process.

1994 Terry Winograd

Designing the Designer (Winograd, 1994)

Brown and Duguid's Article [Brown and Duguid (1994)] reflects a growing awareness that HCI has a social and a communicative dimension, which is equally central to the field as the psychological and cognitive issues that have long been at its core.

1994 Gary Strong et al.

New Directions in Human Computer Interaction (Strong et al., 1994, pp 26)

HCI research should probably confront human-human communication as the first order approximation of information transfer and study that. As development then works to make HCI more seamless with human-human interaction, success will be assured because interaction will then be transparent in the hands of the user, allowing the user to focus complete attention on the tasks at hand.

1996 Jean B. Gasen

HCI Education: Past, Present, and Future? (Gasen, 1996, p 25-26)

The emphasis on the social contexts of computing will become more important as everyone considers ways in which technology is metamorphosing communication at a global level.

1996 Brad Myers et al.

Strategic Directions in Human-Computer Interaction (Myers et al., 1996)

Human-computer interaction (HCI) is the study of how people design, implement, and use interactive systems and how computers affect individuals, organizations, and society. This encompasses not only ease of use but also new interaction techniques for supporting user tasks, providing better access to information, and creating more powerful forms of communication.

Table 1.1: **HCI and the study of communication**

The historical relation between computing and communication can be traced across the several ACM Curricula recommendations.

Briefly, in **Curriculum 68** there were proposed courses on: (a) Formal Languages and Syntactic Analysis (b) Information Organization and Retrieval in which semiformal languages and models for the representation of structured information, as well as several methods for natural language analysis and evaluation were presented. (c) Computer Graphics, which were aimed at the study of handling graphic information in computers and its applications (d) Artificial Intelligence and Heuristic Programming, which introduced students to non-arithmetic applications of computing machines and issues related to cognition and intelligence. There were several other courses in common with engineering, and Large Scale Information Processing Systems certainly intersected with Information Systems.

In **Curriculum'78**, natural language processing and non-arithmetic issues were diluted into a topic of Artificial Intelligence, large scale information systems were narrowed to file-processing and database management, computer graphics disappeared, and an advanced course on computers and society was proposed, but seldom implemented. Formal languages remained in an elective course on Automata, Computability, and Formal Languages.

In **Curricula 1991**, formal languages topics were listed within the areas of Algorithms and Programming Languages. Human-Computer Communication, basically interfaces and computer graphics, was introduced. Restricted topics in information retrieval, natural language, and social and ethical issues were listed as sub-topics of Database and Information Retrieval, and Artificial Intelligence. The social and professional context was included but not clearly emphasized.

In **Curricula 2001**, draft version of March 2000, formal languages are an item in automata theory within the area of Algorithms and complexity. Human-Computer Interaction and Computer graphics will be included; natural language processing is a topic of Intelligent Systems; Collaboration and groupware technology is a topic of net-centric Computing; Social and Professional Issues are clearly emphasized; and Databases turns into Information Management.

In 2001 the committee subdivided the curricula in five strands, emphasizing the relations among four branches of Informatics: Computer Engineering, Software Engineering, Computer Science, and Information Systems.

Table 1.2: **Communication in computer science curricula.** See Chapter 1 for detailed references.

been criticized for being excessively narrow. Within the framework introduced here, Chomsky's formalization of syntactical structures are quasi-independent linguistic strata (levels). Indeed, as the first sentences of "Syntactic Structures", Chomsky wrote:

1957 Noam Chomsky

Syntactic Structures (Chomsky, 1957, Preface)

This study deals with syntactic structure both in the broad sense (as opposed to semantics) and the narrow sense (as opposed to phonemics and morphology). It forms part of an attempt to construct a formalized general theory of linguistic structure and to explore the foundations of such a theory.

In that book, Chomsky dedicated a specific chapter to syntax and semantics. In it, he clearly discusses the relation of the syntactical level of language to the phonologic, morphologic and semantic ones. Chomsky clearly stated that only a broader theory of language, one that included the theory of linguistic form and theory of linguistic use, would be capable of addressing the correspondence between formal and semantic traces (Chomsky, 1957, 9.3). Indeed, Chomsky also stated that to understand a sentence, knowledge about each linguistic level was not enough, because notions such as sense and reference, which belonged to the domain of semantics, were necessary (Chomsky, 1980, section 9.1, p 113) and Chomsky (1957).

The assumed independence of Chomsky's levels facilitated the segmentation of language studies into several strata and its appropriation by Informatics. For example, computer scientists appropriated the notion of syntax, and with some exceptions, discarded all the other parts of language studies necessary to understand effective communication.[2]

In Figure 1.1 I have briefly sketched a conceptual diagram in which the concepts used by several authors in the theory of computing, logic, linguistics, language studies,

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[2] Behind this brief comment on linguistics and computer science resides my deep criticisms about the boundaries that have been set in Informatics in what concerns language understanding in a broad sense.

and semiotics are plotted. The diagram is only illustrative, because the ambiguity, and the uses and misuses of terms such as syntactics, semantics, and pragmatics, does not enable a direct comparison between them and across authors. [3]

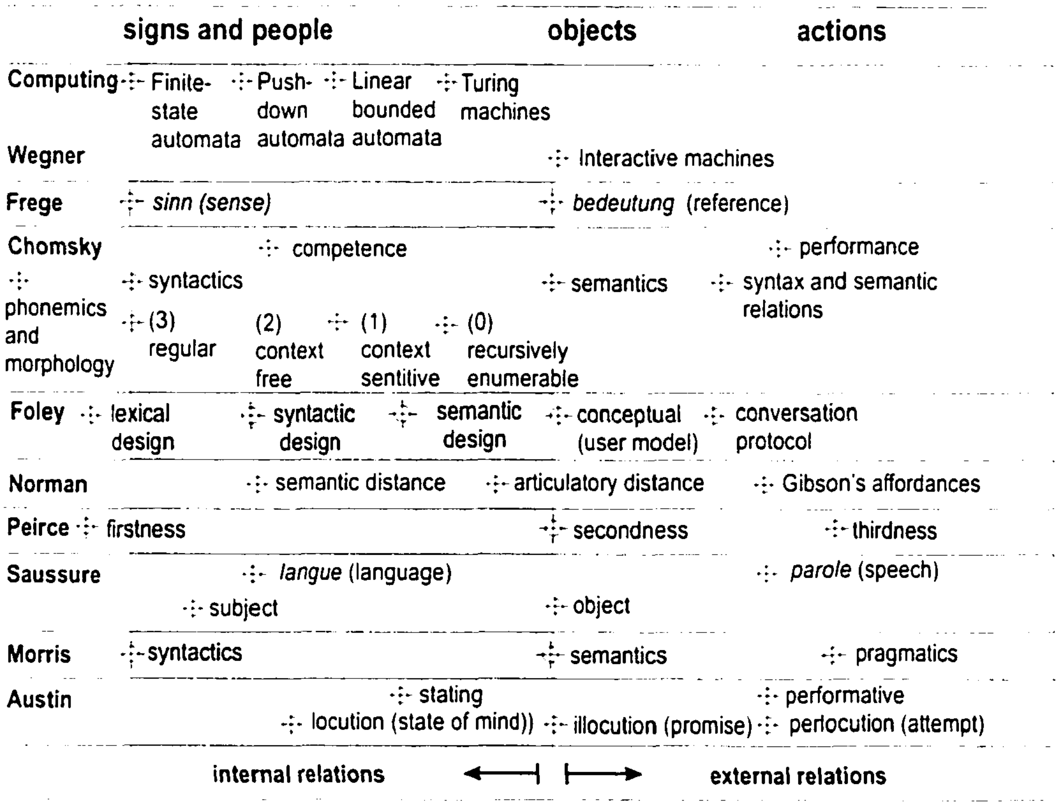

Figure 4.1: **Examples of language scales and hierarchies**

However, it is possible to note that despite the differences and contradictions,[4] the

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[3] The conflation of signs, people, and computers to single columns intend to facilitate this brief comparison among different scopes. It flattens out their differences. For example, Figure 4.1 depicts people's cognitive systems in the same columns as computing processing architectures, a decision with which only some approaches in cognitive science would agree. Independence or connectedness between columns is also not depicted. More dimensions are needed to distinguish different approaches, and that is what is proposed in this thesis with 3D models.

[4] It is not uncommon to use the term semantics of computer languages to denote the objects inside the computer itself. This use is closer to what Chomsky called the phonemic and morphological level, because they imply the substrate languages are expressed in. The separation between hardware and software probably reinforces this perspective.

realm of computing has the most restricted understanding of language of all. Within the theoretical framework adopted in informatics, (see Figure 4.1's dark gray dashed rectangle) there is no space for functionality (Foley's level of semantic design), for usage (Chomsky's distinction of competence and performance and Austin's concepts of illocutionary and perlocutionary acts), for actual interaction (Norman's articulatory distance and Gibson's concept of affordance), and for the usual meanings of semantics and pragmatics in linguistics, semiotics, and language studies in general.

Interactive machines do not represent the standard view in Informatics, but represent a example of a model that opens abstract machines to interact with the world.[5]

The historical consolidation of Informatics diverged in terms of communication. It is undeniable that the influence of Informatics on communications has increased. It is also undeniable the great depth that theoretical models of machines and grammars have achieved, and the widespread uses of computer languages. However, in terms of breadth, Informatics falls short in terms of theoretical frameworks of language, communication, and interaction in the broad sense (e.g. semantics, performance, and pragmatics).

Paul Adler and Terry Winograd, for example, addressed the inseparability of computer based systems design from communication in the broad sense (as encompassing semantics and pragmatics). Adler and Winograd wrote:

> 1992 Paul S. Adler and Terry Winograd *The Usability Challenge* (Adler and Winograd, 1992, p 3)
>
> To break free with the prevalent myths and go beyond current practice, we must articulate new criteria that are appropriate to the tasks of modern computer-based system design and the interwoven tasks of work design. [...]

---

[5] Models such as the Universal Turing machine, widely used in computer science, and the basis of algorithms, do not interact with the world. Peter Wegner, the same author who wrote about the three cultures of computing in the early seventies, has recently proposed extending the concept of abstract machine by adding a notion of interaction. Wegner called such an extended model interaction machines. See Wegner (1995, 1997, 1998); Wegner and Goldin (1999) and Chapter 3. Indeed, computer scientists have been reductionist by calling Turing Machines universal.

> Usability [...] assumes a communications dimension. The technology itself, even when it is not intended as a communication product, serves as a communication medium between user and user and between designer and user. A realistic characterization of work – even routine work – is that it is essentially entwined with communicative actions generated to deal with the novel situations that continually arise and with the need to interpret the intentions embodied in the machines.

In the second part of this thesis I actually address design in informatics as communication. In Chapter 3 I address various models of communication, interaction, organizational change, and design processes in the light of the cultural ecology of HCI, as discussed until now. I use these models to discuss, for example, the limitations of Norman's gulfs of execution and evaluation in terms of pragmatics, and of Moore's "chasm" model of technology acceptance. Some of these models make use of terms such as semantics and pragmatics, but there is no consistency across the different uses given to them.

In this Chapter I explore the theoretical framework that later contributed to the consolidation of the terms syntactics, semantics, and pragmatics, showing that the confusions and contradictions are not a peculiarity of HCI and Informatics. Indeed, they have been a constant in semiotics since its inception in the nineteenth century. In the fourth chapter, I make extensive use of frameworks developed in engineering and Informatics to systematize Charles Sanders Peirce's several concepts of sign and associated categories.

4.2 Sign Relations

It is undeniable that literacy and numeracy have both been present to varying degrees throughout the development of the intricate cultural matrix that structure some current cultures, in particular the dominant ones. The cultural disciplinary ecology of Semiotics is probably as intricate as the one of Informatics, and in my understanding they are inseparable. However, the communities that study informatics and semiotics have diverged as if these two realms did not intersect.

The broad perspective envisioned in the previous chapters has been important to situate and characterize informatics in relation to itself, and to other disciplines. My discussion of informatics, and computer science in particular, suggests it has been restricted to syntactic views, rather than broader ones.

I started this thesis with an eye on the broader bridge between semiotics and computer science. At several points I have pointed to possible links between informatics and semiotics. In any work the goal, the horizon, the whole context are necessary, but not sufficient. I will conclude this thesis with a much narrower topic in semiotics, as I mentioned before. In particular, I address a small topic in semiotics with the aid of frameworks developed in the computing sciences and engineering. The focus is on partial orders in Peirce's sign relations and associated categories. I do not address in detail what a sign is, what its components stand for, or what practices can be enriched with semiotics. Therefore, it does not encompass even the sign relation in its full breadth.

The sign relation, in its many possible definitions, has been the key element across the cultural ecology of semiotics. For example, dyadic, triadic, and cultural mediations have been deeply entwined within the developed identities of Semiology, Semiotics, and Cultural Historical Activity Theory.

I grouped in Figure 4.2 some diagrams developed in three semiotics schools in order to illustrate the diversity that permeates the field and the associated frameworks that structure the respective sign relations. The lines of Figure 4.2 are organized according to the legacy of these three schools, which sustained and further developed the work of Ferdinand de Saussure (1857–1913), Charles Sanders Santiago Peirce (1839-1914), and Lev Semenovich Vygotsky (1896-1934), respectively. Figure 4.2(a) illustrates Saussure's concept of sign re-read by (Thibault, 1997, p 182) in the light of a social perspective. As I have discussed in the preceding chapter, structuralism differentiated structure from use in order to discard use. It discarded the individual from the subject of linguistics. Paul Thibault rescued the speaker-listener, giving a triadic structure to Saussure's relation between sound and thought (Thibault, 1997, p 182). Figure 4.2(b) illustrates a diagram developed by Louis Hjelmslev Hjelmslev

(1975), who stratified Saussure's model. In this stratification, both expression and content are correlated with a scale that starts on purport (amorphous matter), passes through substance, and reaches form (Nöth, 1995, pp 64-73).

Indeed, the main contribution of this chapter is a systematization of similar resources used by Peirce to elaborate his several structures of sign relations and their corresponding categories. As illustrated in Figure 4.2(c), Peirce's most known sign relation[6] is triadic and it is composed of representamen, object and interpretant. In Peirce's own words:

> A **Representamen** is a subject of a triadic relation **to** a second, called its **Object**, **for** a third, called its **Interpretant**, this triadic relation being such that the **Representamen** determines the interpretant to stand in some triadic relation to the same object for some interpretant (Peirce, 1931-1935, 1.541).

In 1904, Peirce defined the cenopythagorean categories of *Firstness*, *Secondness*, and *Thirdness* in respect to their mode of being (Peirce, 1958, 8.328) in a letter to Lady Welby as:

> **Firstness** is the mode of being of that is such as it is, positively and without reference to anything else. **Secondness** is the mode of being of that is such as it is, in bringing a second but regardless of any third. **Thirdness** is the mode of being of that which is such as it is, in bringing a second and a third into relation to each other. I call these three ideas the **cenopythagorean categories** (Peirce, 1958, 8.238).

Peirce correlated the triadic sign relation (R,O,I) with the cenopythagorean categories (I,II,III) to derive classes of signs. He also explored hexadic and decadic sign relations, which I explore later in the final sections of this chapter. Before I focus on the derivation of classes of signs and the several graphic formalisms proposed to visualize it, I proceed with a contextualization of the sign within semiotics, within Peirce's systematic philosophy, and within computer semiotics.

Figure 4.2(d) illustrates one version of the widely disseminated semiotic triangle introduced by Charles Kay Ogden and Ivor Armstrong Richards. As Nöth (1995, p

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[6] See Marty (1997) for seventy-six related definitions of the sign found across Peirce's work.

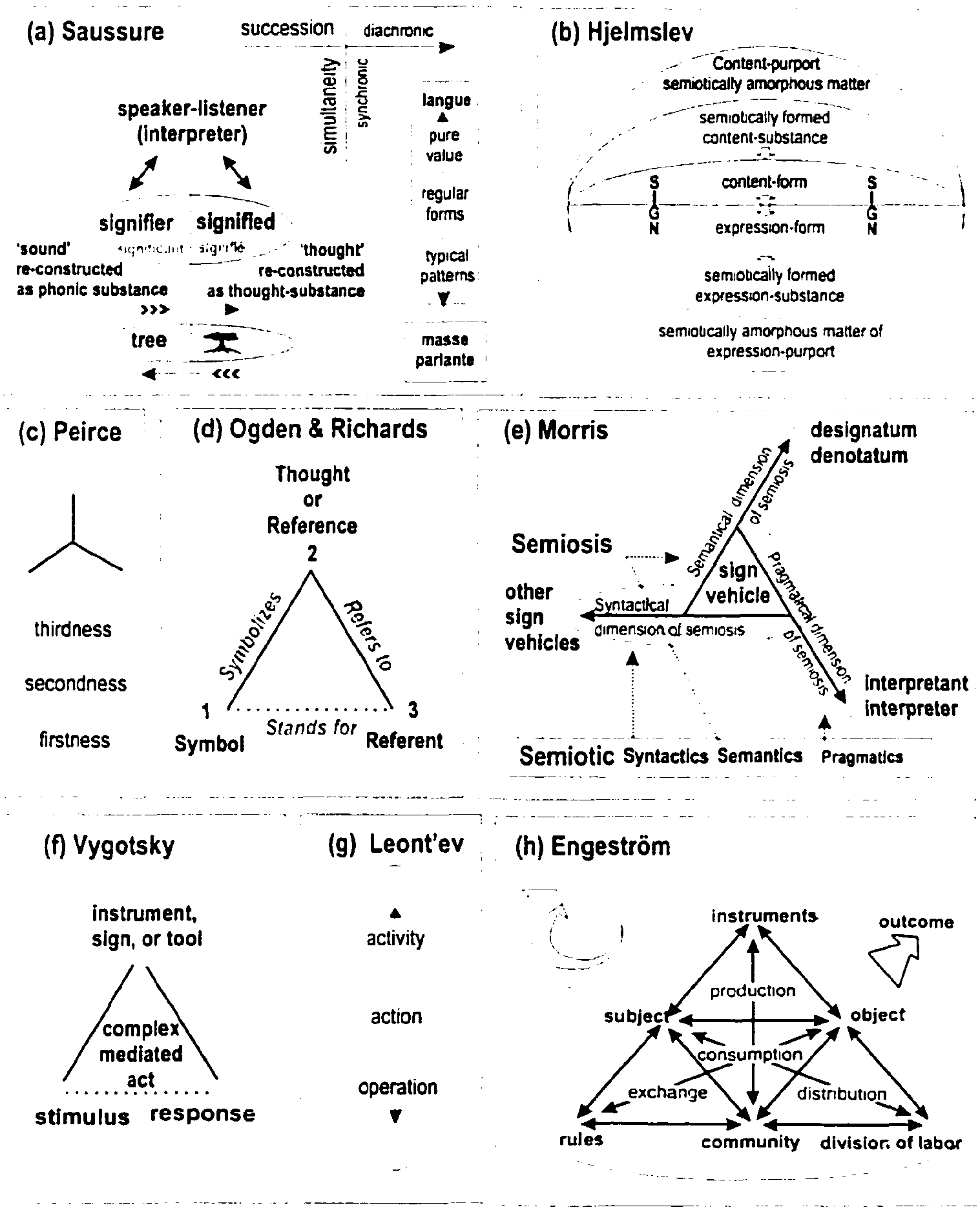

Figure 1.2: **Examples of sign relations across semiotics schools:** based on (a) Thibault (1997, p 182); (b) Hjelmslev (1975); (c) Peirce (1931-1935, 1.541); (d) Morris (Nöth, 1995, p 89) (f) Ogden & Richards (Nöth, 1995, p 89) (g) Vygotsky (1978, p 40) (h) Leont'ev (1978); and (i) Engeström (1987).

89) pointed out, although there has been agreement in the use of a triangular form to illustrate sign triadic relations, there has been agreement neither on what the vertices or edges stand for, nor on their order.[7]

Two recurrent tendencies that I mention across this thesis are the tendency in communication and informatics to linearize what is not linear and isolate and close what is connected and open. Morris developed a "General Theory of Signs" in which he correlated his three components of the sign into three dyads and associated each with syntactics, semantics, and pragmatics. As I address in this Chapter, the pattern across Peirce's work indicates a enclosing nature of syntactics, semantics, and pragmatics. This is clear in Peirce's sign relation, in the derived categories, and across his systematic philosophy. However, syntactics, semantics, and pragmatics are linked by dyadic relation among the elements of a sign relation, which is obvious from following Morris' illustration in Figure 4.2(e). This indeed reduces triadic semiotics to dyadic semiotics and does not do justice to Peirce's work.

According to Nöth (1995, p 90) "More generally, the order (1) sense (2) sign vehicle (3) object is the order of semiosis from the point of view of sign production, while the order (1) sign vehicle (2) sense (3) referent is the order of semiosis from the point of view of the interpreter."[8]

The extension of the sign described in Peircean and Saussurean semiotics also has its parallel in Cultural and Historical Activity Theory. Engeström (1987) extended Vygotsky's concept of mediation (Figure 4.2(f)) correlating it with Leont'ev (1978)'s levels of activity (Figure 4.2(g)), obtaining the extended triangle of Figure 4.2(h).

Each new diagram introduced in the literature brings other voices to the scene, stressing different perspectives in the understanding of meaningful relations. Overall, there has been no consensus within this specialized community.

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[7] Examples include: Plato ((1) sound (2) idea or content (3) thing) Aristotle ((1) sign-vehicle (2) sense (3) referent)); Ogden & Richards ((1) symbol (2) thought or reference (3) referent); Charles William Morris (1901-1979) ((1) sign vehicle (2) significatum (3) denotable) in Figure 4.2(e); and Vygotsky ((1) stimulus (2) instrument, sign or tool (3) response) on Figure 4.2(f), among others.

[8] Semiosis is the process associated with the concept of sign. It is a semiotic process.

One should not be tempted to ask "who is right?", "which order is the correct one?", or "what comes first and what comes next in semiosis?". The discussion has been fruitful only in the sense that the quarrels have sustained the main paradigm which the community claim it has been criticizing. These questions already give the answer, that there is a strictly ordered sequence for semiotic processes. This would be in accordance with Cartesian perspectives and the information-processing paradigm. In the end, almost everyone has been arguing, but according to the rules of Cartesian thought. Peirce, however, went way beyond Descartes.

Included in the remainder of this chapter several examples in Semiotics of attempts to linearize Peirce's signs into chains, as well as its corresponding categories. These proposals bring nothing new to the scene. It is possible, however, to say that a certain chosen order is in accordance with such and such an author, or to show that even assuming relations of order, they are not strictly sequential.

I proceed with a discussion of relations of presupposition across Peirce's systematic philosophy. This will give the reader a shallow but broad view of Peirce's work.

For example, Peirce subdivided the science of Semiotics in three branches: pure grammar, logic, and pure rhetoric (Peirce, 1931-1935, CP 2.229). Later on, he called them speculative grammar, critic, and methodeutic, respectively. He also stated that pure rhetoric presupposes logic, which in turn presupposes grammar. Peirce described these areas in the following passage:[9]

> "In consequence of every representamen being thus connected with three things, the ground, the object, and the interpretant, the science of semiotics has three branches. The first is called by Duns Scotus **grammatica speculativa**. We may term it **pure grammar**. It has for its task to ascertain what must be true of the representamen used by every scientific [capable of learning by experience] intelligence in order that they may embody any **meaning**. The second is logic proper. It is the science of the quasi-necessarily true of the representamina of any scientific

---

[9] The reader my have noted that instead of representamen, Peirce used "ground" in this passage. Peirce varied a lot in his terminology in order either to refine his framework or to be better understood.

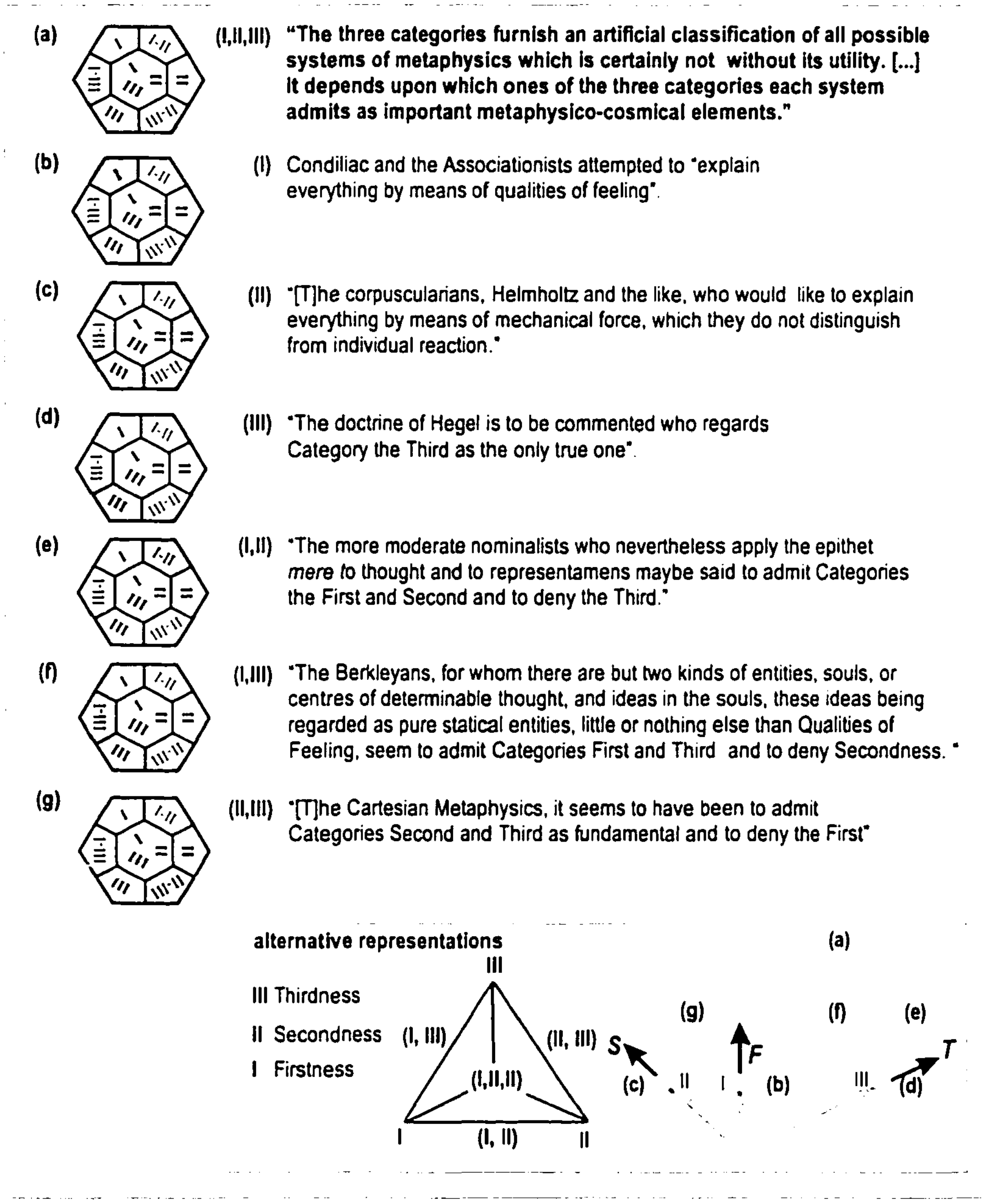
> intelligence in order that they may hold good of any **object**, that is, may be true. Or say, logic proper is the formal science of the conditions of the truth of representations. The third, in imitation of Kant's fashion of preserving old associations of words in finding nomenclature for new conceptions, I call **pure rhetoric**. Its task is to ascertain the laws by which in every scientific intelligence one sign gives birth to another, and specially one thought brings forth another."(Peirce, 1931-1935, CP 2.229)

For Peirce, logic or semiotics presupposes ethics and esthetics. This implies that semiotics is focused on representations, but presupposes action and perception. This same pattern is also present in Peirce's description of several branches of metaphysics, as illustrated on Figure 4.3 (Peirce, 1997, p 172) (Peirce, 1931-1935, p 53, 5.79). Peirce used a hexagon to explore the nebulae of interests of six different schools represented by: (a) his own metaphysics; (b) Condillac and the associationists; (c) Helmholtz and the corpuscularians; (d) Hegel; (e) the Nominalists ; (f) the Berkleyeans; and (g) Descartes. In Peirce's explanation, for example, Cartesian metaphysics seems to admit categories the second and the third, and deny category the first which is related to qualities of feeling.

Throughout the twentieth century, however, the focus of semiotics has been mostly restricted to Peirce's "pure grammar" (speculative grammar) and logic (critic), but narrowly understood, as if these were independent of ethics and esthetics. In this sense, the maintenance of the traditional reductionist perspective has continued. As I said above, most Peircean semioticians, despite their quarrels with structuralists, endorse a tampered Cartesian and dichotomous praxis.

An historical and cultural understanding of the associated implications may render a whole thesis in semiotics. The joint development of semiotics and informatics will probably benefit from such a discussion. I do not feel that this is the appropriate venue to deeply discuss these issues in the full breadth that is necessary. Informatics, however, can deeply contribute to this discussion.

Computer Science may have been theoretically restricted mainly to the structural aspects of language, but in parallel, it developed a myriad of resources to organize and



(a) (I,II,III) **"The three categories furnish an artificial classification of all possible systems of metaphysics which is certainly not without its utility. [...] It depends upon which ones of the three categories each system admits as important metaphysico-cosmical elements."**

(b) (I) Condillac and the Associationists attempted to "explain everything by means of qualities of feeling".

(c) (II) "[T]he corpuscularians, Helmholtz and the like, who would like to explain everything by means of mechanical force, which they do not distinguish from individual reaction."

(d) (III) "The doctrine of Hegel is to be commented who regards Category the Third as the only true one".

(e) (I,II) "The more moderate nominalists who nevertheless apply the epithet *mere* to thought and to representamens maybe said to admit Categories the First and Second and to deny the Third."

(f) (I,III) "The Berkleyans, for whom there are but two kinds of entities, souls, or centres of determinable thought, and ideas in the souls, these ideas being regarded as pure statical entities, little or nothing else than Qualities of Feeling, seem to admit Categories First and Third and to deny Secondness."

(g) (II,III) "[T]he Cartesian Metaphysics, it seems to have been to admit Categories Second and Third as fundamental and to deny the First"

Figure 4.3: **Metaphysics' nebulae of interest:** Peirce's illustration of the six systems of metaphysics and their emphasis on specific categories (Peirce, 1997, p 172)(Peirce, 1931-1935, p 53, 5.79)

visualize relations of data in consonance with areas in which it intervened. Throughout this chapter I'll make use of several of these resources, mostly developed or refined in areas commonly labeled "data structures" and "discrete mathematics."[10] My objective is to facilitate the understanding of a part of Peirce's work in the depth and breadth that it deserves.

One such resource is an arborescent structure known as a "tree", which can be binary, ternary, quaternary, etc. Trees are a special kind of network, and they particularly suit the representation of subdivisions and hierarchies. There are several forms and conventions to visualize trees. I organized the diagram in Figure 1 according to the recursive subdivision of Peirce's philosophy (from left to right), and from the relations of presupposition (from top to bottom) with the aid of a common visualization of a tree.

The subject matter of "discrete mathematics" includes to a large extent finite collections, which I plotted at the bottom of Figure 1. For Peirce, mathematics presupposes no other sciences. At the top of the diagram is the node depicting the practical sciences like pedagogics, implying that they presuppose all others. I would include informatics in such a node. Within Peirce's framework, this means that informatics would presuppose physics, psychology, and philosophy. Philosophy itself encompasses most of the diagram, including semiotics, which is labeled as logic.

The reader may be curious about the motives that lead me to return into structure again, after three chapters, and an introduction of a fourth one claiming the importance of a broader understanding of design in informatics and HCI. The reason is straightforward. The notion of structure that I am proposing here is open, rather than closed. It is an open structure deeply entwined within the context that it is part of. It stresses the relational aspects of sign relations, rather than its components.

The scope of the following sections is reduced accordingly. In relation to Peirce's philosophy, they go at most at the subject of Peirce's speculative grammar and their relation with phenomenology and mathematics as finite collections. There will be a

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[10] Most curricula in informatics have "data structures" and "discrete mathematics" as core disciplines.

long stretch yet to explore along the gap between informatics and semiotics, both broadly understood.

4.3 Ternary Sign Relation in Informatics

The recent interdisciplinary interest established across informatics and semiotics has many examples of different orders in which sign relations and semiotic processes are depicted. I grouped some examples in Figure 4.4.

The influence on Mihai Nadin's (1988, p 271) diagrams of Peirce's, Ogden and Richards', and Morris' works is clear, as illustrated in Figure 4.4(a). Multiple influences can be illustrated by two examples. Nadin used the triangle to depict the triadic sign relation, which was introduced by Ogden & Richards. In addition, the components, follow Peirce's terminology of Representamen, Object, and Interpretant. But the relation between components are dyadic, which could lead to Morris' syntactics, semantics, and pragmatics, and not to Peirce's sign relations and categories, which were triadic. However, Nadin depicts these three branches not as Morris did, but following Peirce's relations of prescision among the cenopythagorean categories.

The next four examples address recent cross-pollination between informatics and semiotics. They all bring the voice of linear noiseless communication models, discussed in the previous chapter, which I called the pipe or duct model of communication. Jorna and van Heusden (1996, p 238), illustrated in Figure 4.4(c), associated timely ordered presentation, interpretation and representation to describe systems analysts' roles in designing computers and interfaces based on the real world. These concepts could be easily related to objects, interpretants, and representations (O.I.R). For the user, however, the representation becomes presentation, and it is interpreted (O.I).[11]

Figure 4.4(d) illustrates a second example in this same order (O.I.R). Falkenberg et al. explicitly dichotomized a triadic sign relation into a process of interpretation

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[11] The linearization in the diagram in Figure 4.4(c). Nevertheless, Jorna and van Heusden (1996, p 238) discussed Boisot's information space, and went beyond the linear model.

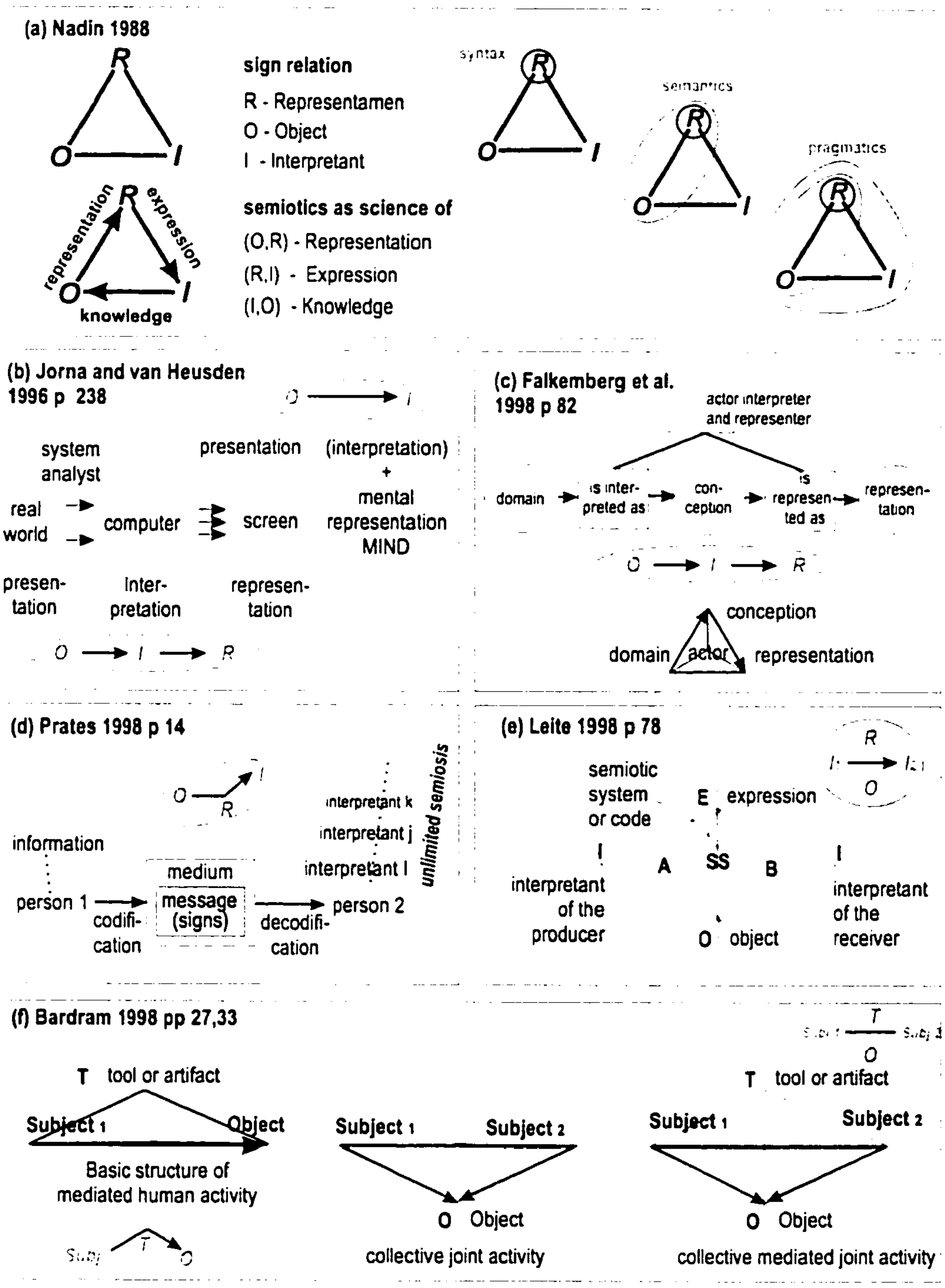

Figure 1.1: **Semiosis in Informatics and Organizations:** based on (a) Nadin (1988, p 271); (b) Jorna and van Heusden (1996, p 238); (c) Falkenberg et al. (1998, p 82); (d) Prates (1998, p 14); (e) Leite (1998, p 78) (f) Bardram (1998, pp 27,33)

that transforms the domain into concepts, followed by a process of representation that transforms concepts into representations (O.I.R) (Falkenberg et al., 1998, p 82). Using this framework they distinguished different levels forming the following strata, which starts with the lowest one: the physical world, empirics, syntactics, semantics, pragmatics, and the social world. The authors explicitly mentioned Morris' branches, and went beyond them, including elements of communication channels and cultural ones.

Raquel Oliveira Prates, working in semiotic engineering (de Souza, 1993), also linearly streamed Peirce's triangle into a sequence that goes from designer's information, passes through the designed artifact, and it finally is unboundedlly interpreted (O.R.I.I.I....) (Prates, 1998, p 14).[12] See Figure 4.4(e). Leite (1998, p 78), working in the same research line, dichotomizes the triadic relation into expression and object (structuralism), as depicted in Figure 4.4(f). However, Leite reintroduced interpretants through roles of producers (designers) and receivers (users), organized sequentially organized. Leite clearly refers to Peirce and uses the triangle. However, in my understanding of both the sign components and also its extensions, having the sign system orthogonal to the time dimension[13] superimposes a structuralist perspective.

For other work on the relation between semiotics and informatics, broadly understood, see Appendix E.

4.4 Categories of Ternary Sign Relations

As I have already mentioned, there has been no agreement either on components or on the organization of sign relations. In the field of informatics, however, within the fields of data structures and discrete mathematics, different forms of organization of

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[12] Peirce's notion of unlimited semiosis was tied to one of a perfect sign, one in thirdness. According to him, if for whatever reason the process determines no outward sign, vanishes, or becomes annihilated, it become unrescuable, "absolutely undiscoverable that there ever was that idea in that consciousness" (Peirce, 1931-1935, 2.303).

[13] Saussure's distinction between the diachronic and the synchronic.

information have been studied and developed in consonance with the problems faced during their development. There are several ways of structuring the same problem. Some are interchangeable in terms of structure, but they have different performances in terms of operations.[14] An experienced professional, however, is able to decide which data structure is more indicated by a certain problem, considering the involved constraints. When the problem demands it , the professional may develop new forms of organization, or adapt current ones, according to desired results.

In this and in the following sections, I explore several "structures" developed within informatics, including trees, tables, and lattices, to organize and visualize Peirce's ternary sign relations. The emphases are on the relations between the elements, and not on the meanings or concepts associated with them. In this sense, I am falling into the structuralist pit in order to characterize its boundaries. I have abstracted away what the components of a sign relation stand for to focus on the relations of order among them. Therefore, it does not matter within these context if these components stand for meanings, subjects, interpretants, representamina, objects, referents, etc. The focus is on the relation under which the set of components is structured.

I remark that this is not just a application of data structures to semiotics. As I hope I have shown in the preceding chapters, the dialogic relation of "computing, communication, and information" with the world and with people is fundamental to open the conceptually closed computing artifact to its context. Moreover, the work I discuss here is only an initial exploration of a possible new direction of theoretical work in computer science.[15]

This discussion is not limited to the usual theoretical realms in semiotics or in informatics. Although its focus is centered on sign relations and corresponding cat-

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[14] This means that the there are several forms of representation, but their appropriateness is contingent to the problem.

[15] The human centered development of topics such as object-oriented programming, patterns, and subject-oriented programming could benefit from semiotic scaffolds. Their frameworks involve the relation between objects, subjects, and forms of representation. This is a topic of interest to me, but one I have left as a future theme of research.

egories, the envisioned horizon encompasses computer science practices and well-established theories. Therefore, I am not doing only informatics or semiotics as they are currently understood, but both.

Across Peirce's work it is possible to find both descriptions of sign relations as well as classifications of sign relations with different numbers of elements. The sign relation that Peirce developed the most is the triadic one. The terminology of each component varied, but their order remained mostly constant.

There are twenty-seven (3^3) ways of arranging three distinct elements in a sequential order. In Figure 4.5 the possible arrangement of three elements, represented as 1, 2, and 3, are depicted in a tabular sequential diagram.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
111												**221**						**311**				**322**		**331**		**333**
									211				**222**								**321**				**332**	
1									2			3	4					5			6	7		8	9	10

Figure 4.5: **The 10 valid arrangements that satisfy the prescision constraint.**

Peirce's concept of prescision[16] encompasses a relation of order between firstness, secondness, and thirdness; or between Representamen, Object, and Interpretant. It is this same relation of order that is found as a organizing principle in his systematic philosophy. For example, thirdness always presupposes secondness and firstness, and secondness always presupposes firstness. The prescision constraint exclude seventeen possibilities among the twenty-seven possible ones. Associating Peirce's concept of prescision with numbers, it implies that the first correlate cannot be smaller than the second, which cannot be smaller than the third. In terms of a triadic sign relation encompassing Representamen, Object, and Interpretant, this implies for example that:

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[16] To prescind from something, means to cut of to leave it out of consideration.

[R,–,–] It is possible to consider representamina in themselves;

[R,O,–] It is possible to consider the relationship between representamina and their objects;

[–,O,–] It is impossible to consider the relationship between representamina and their objects if there are no objects.

[R,O,I] It is possible to consider the triadic relationship of representamina representing their objects to interpretants.

[–,–,I] It is impossible to consider interpretants if there are neither objects nor representamina.

In Figure 4.5 I sequentially labelled the ten combinations sequentially having the first digit larger or equal to the second, and second larger or equal to the third.

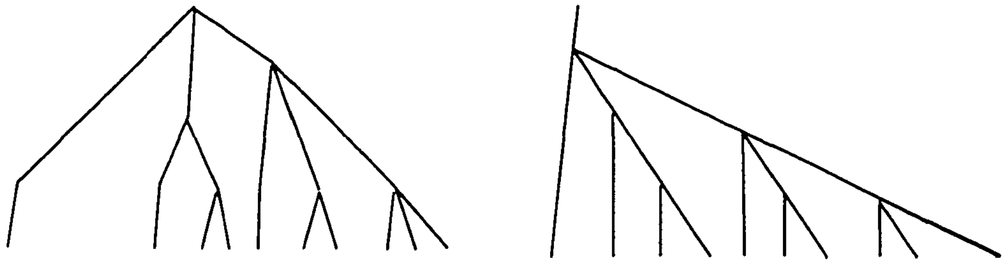

Figure 4.6: **Peirce's arborescent diagram of the ten categories of triadic signs** (Peirce, 1997, p 169, redrawn)

One resource to graphically depict the sequential combination of three elements is an arborescent diagram. In a series of lectures on pragmatism given by Peirce at Harvard in 1903 he used the illustration in Figure 4.6 to defend his classification of signs into ten categories (Peirce, 1997, p 169, redrawn).[17] This kind of diagram is well-known in informatics. Indeed, there are many forms of representation of arborescent diagrams, or trees, as they are called in computer science.

In ternary trees each node may be subdivided into at most three other nodes, as illustrated in Figure 4.7. Peirce's arborescent diagrams correspond to the bold lines

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[17] This illustration has not been included in the collected papers.

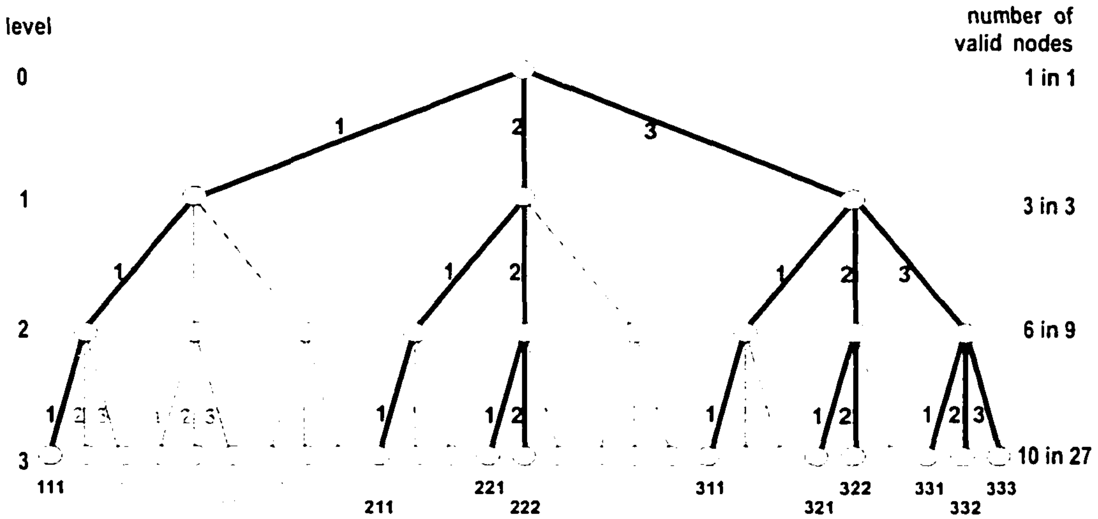

Figure 1.7: **Ternary tree of the 10 valid arrangements among the 27**

in Figure 1.7, but in a different graphic disposition.

In order to make the notation clearer, I have associated the three elements of a ternary sign relation with **R**, **O**, and **I**, which correspond to **Representamen**, **Object** and **Interpretant**. Peirce himself used this sequence to organize the sign relation. Moreover, the correlation between a ternary sign relation (R,O,I) and the cenopythagorean categories is the fundament of Peirce's classification of signs. I have also associated with each letter a subscript index which corresponds to the cenopythagorean categories of firstness (1), secondness (2) and thirdness (3). According to this notation, each Representamen, Object, or Interpretant, the components of a ternary sign relation, can be qualified as in firstness, secondness, or thirdness. From the correlation between n-adic sign relations and the cenopythagorean categories, Peirce derived what he called **n trichotomies**. In the case of a triadic sign relation, the following three trichotomies are derived:

First Trichotomy

R_1 - Representamen × Firstness → (Qualisign)

R_2 - Representamen × Secondness → (Sinsign)

R_3 - Representamen × Thirdness → (Legisign)

Second Trichotomy

O_1 - Object × Firstness → (Icon)

O_2 - Object × Secondness → (Index)

O_3 - Object × Thirdness → (Symbol)

Third Trichotomy

I_1 - Interpretant × Firstness → (Rhema)

I_2 - Interpretant × Secondness → (Dicent)

I_3 - Interpretant × Thirdness → (Argument)

The terms in parentheses correspond to the terminology Peirce used to refer to the elements of each trichotomy. In semiotics and in Peirce's writings once the trichotomies are introduced, they are usually exemplified. I have not exemplified them here for three reasons. Firstly, as I said, I abstracted away their possible meanings and uses. Secondly, I understand that the exemplification clearly reduces the n-adic characteristic of the sign relation to a monadic one. Thirdly, as I have already mentioned, I want to stress the importance of going beyond classificatory schemata.

Peirce's semiosis is triadically relational, and it is in this horizon that he described sign relations and categories of signs. From the possible combinations ternary sign's components, Peirce derived ten categories of signs. Peirce listed and illustrated the corresponding valid categories with a diagram reproduced in Figure 4.8. This appeared in a Syllabus of Certain Topics of Logic, which Peirce prepared for a course to be delivered at the Lowell Institute.[18]

The diagram in Figure 4.8 can be obtained from the collapse of the ternary tree as visualized in Figure 4.9. The numerical indexes of each one of the categories can be obtained either by traversing the tree representation or by imagining the triangular table as if it were a collapsed tree, as visualized in Figure 4.10.[19]

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[18] The reader should be aware that the order of the notation used is the inverse of the order of the English language, which can cause some confusion. For example $R_3O_2I_1$ stands for Rhematic (I_1) Iconic (O_2) Legisign (R_3).

[19] Through a distinct process, Farias and Queiroz (1999, 2000b) further explored triangular indexes in a triangle to arrive at the categories' numerical representations. Their work reproduces several of

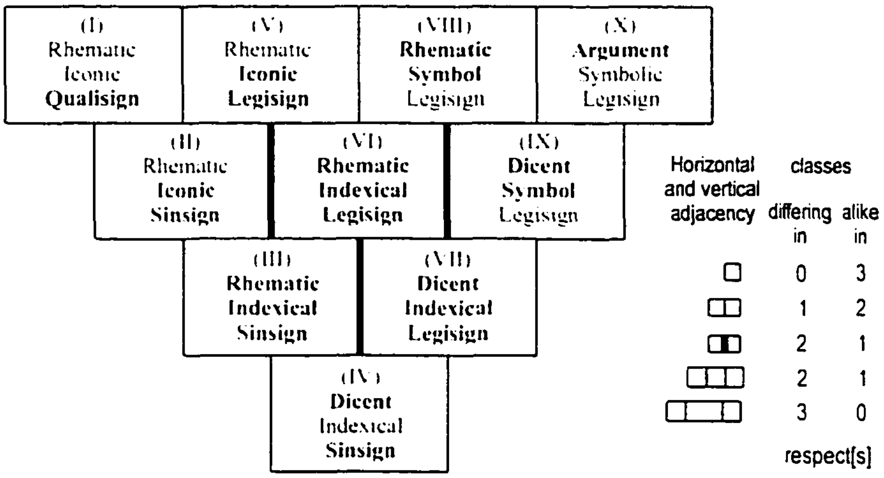

Figure 4.8: **Peirce's diagram depicting the affinities among the ten categories:** (Peirce, 1931-1935, 2.264)

The arborescent diagrams do not enable a full appreciation of the relational characteristics among the ten categories. Peirce was also interested in the relations between the categories, not only in the categories as isolated classification mechanisms.[20]

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the diagrams discussed in this chapter in their original form. I have redrawn most of these diagrams in order to facilitate their comparison.

[20] In twentieth century semiotics, however, classificatory schemata have prevailed, unfortunately. It is not by chance that the most cited of the trichotomies is the second one. It is dyadic and it fits with most of the longer established theoretical and practical frameworks. Within this perspective, both qualities of feeling (first trichotomy) and mediation and habit (third trichotomy) end up de-emphasized. People end up reducing triadic semiotics to a subset that it is not even as large as dyadic semiotics. The tendency of stratification has been strong, and people tend to reduce semiotics to a single stratum, forgetting the relations of presupposition present in Peirce's philosophy, as in classificatory schemes. For example, the classification of a certain sign as an icon, an index, or a symbol, so common in the literature, is only a part of a broader system developed by Peirce to understand semiotic relations. I understand that within Peirce's scaffold, the statement that a particular sign is of a certain kind should necessarily be contingent on historical and subjective factors. In other words, signs should not be frozen as of a certain kind. They can be classified of certain kinds at certain moments and for certain individuals. This means that the same sign, at the same moment, may be of a different kind for someone else, or of a different kind at a different

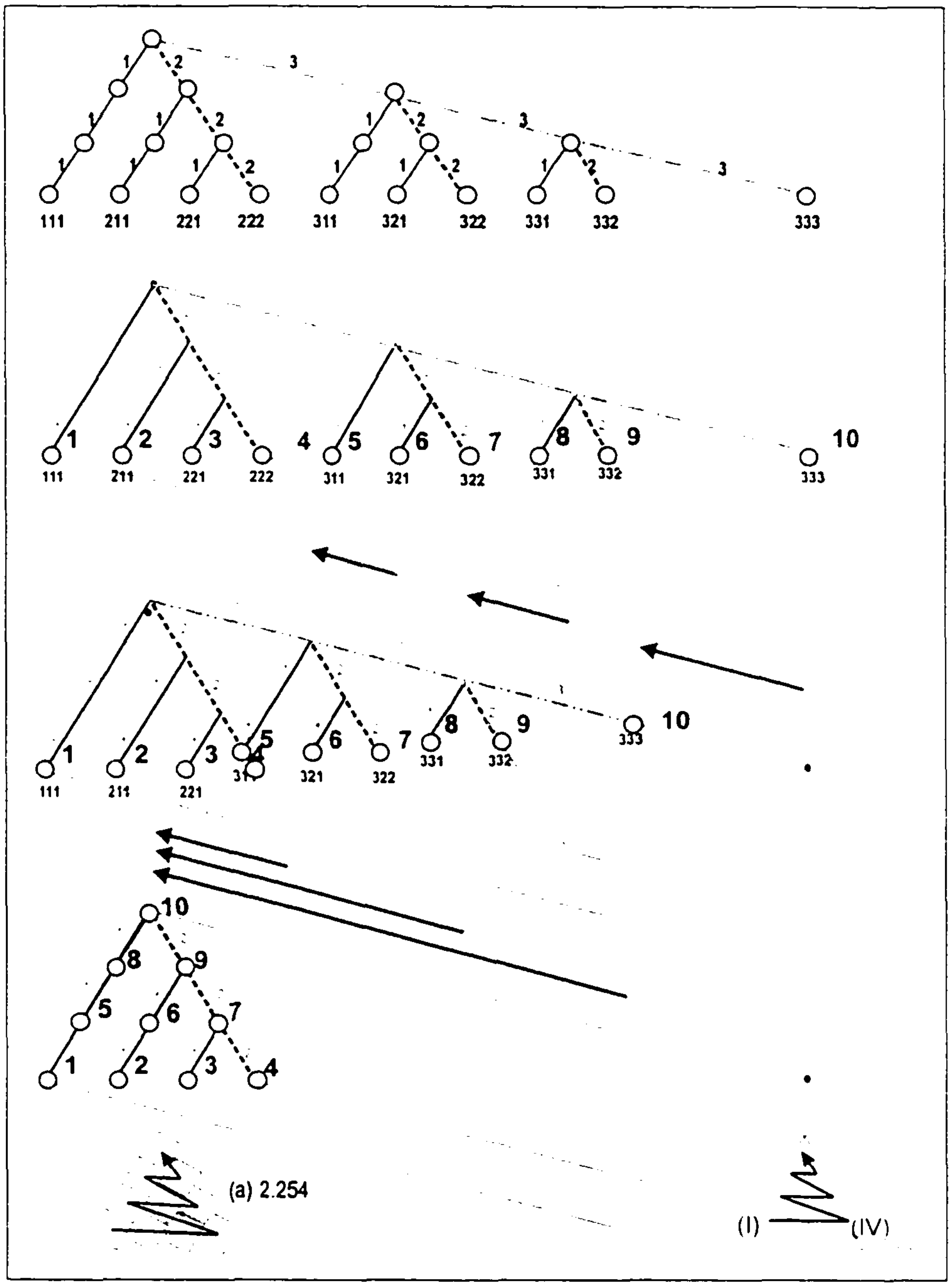

Figure 4.9: **Collapse of the 10 valid arrangements into a triangular diagram** By imagining the tree as enclosed in a parallelepiped, it is possible to collapse the existing planes into a single one. The result is a triangle with ten elements. Peirce used triangular diagrams to describe the affinities between categories. The collapse above enables an understanding of Peirce's diagrams in the light of ternary trees.

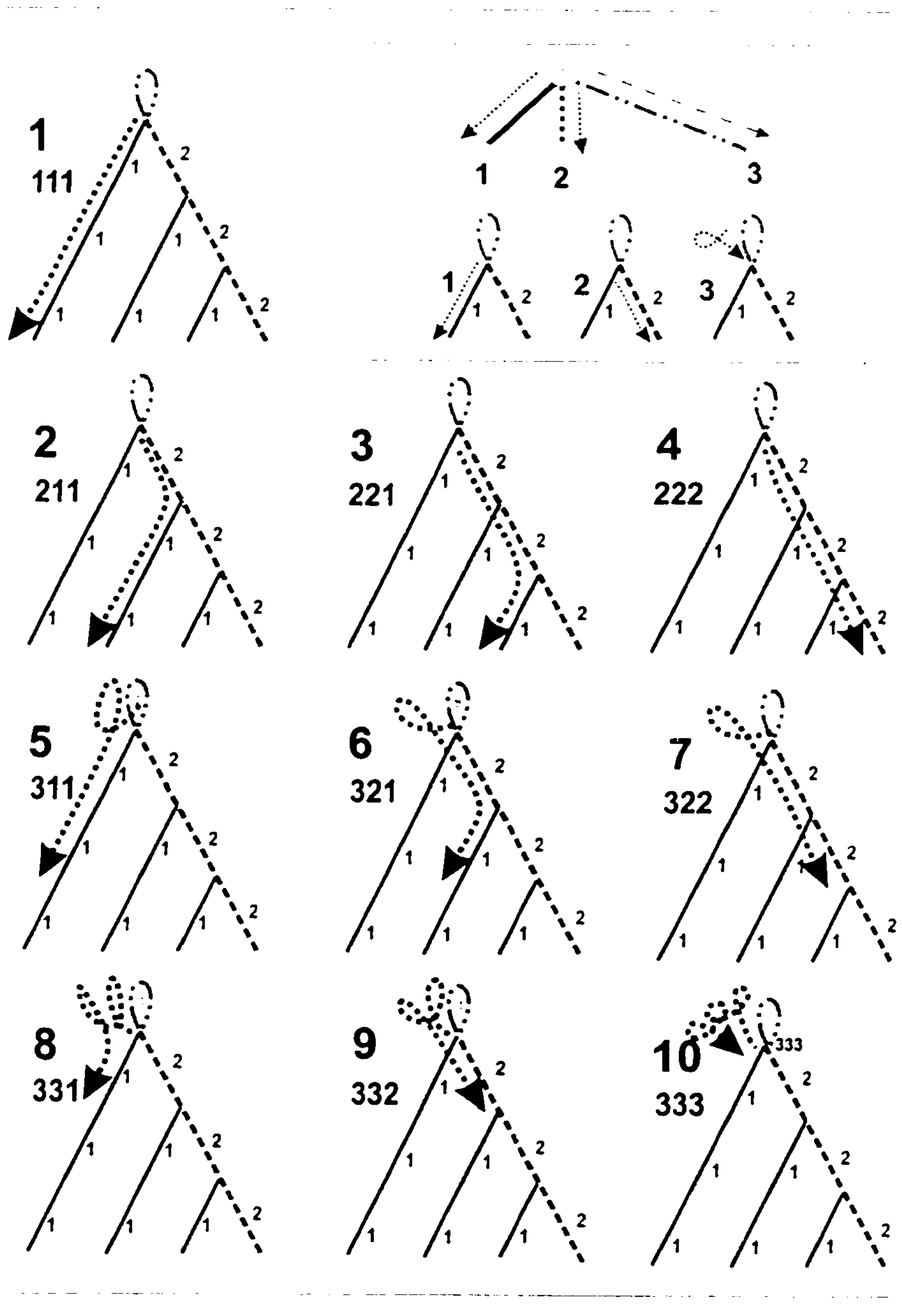

Figure 4.10: **Traversal of triangular representation of the ten categories**

Moreover, he was interested in relations in general even in the most abstracted form.[21]

I proceed now with tabular forms of visualization, both two and three-dimensional. Peirce made use of tables to correlate sets of elements. Tables such as the ones in Figures 4.11(a) and (b) enable the graphical representation of correlation among the elements of two sets.[22] Peirce used 2D and 3D tables to correlate sets. In his own words: (a) "Taking dual individual relatives, for instance, we may arrange them all in an infinite block" (Peirce, 1931-1935, 3.220) (b) "In the same way, triple individual relatives may be arranged in a cube, and so forth" (Peirce, 1931-1935, 3.320).[23]

If one set is composed of the elements of a ternary sign relation (R,O,I), and the second set is composed by the cenopythagorean categories (1,2,3), the correlation produces nine ordered pairs, as depicted in Figure 4.11(g), which correspond exactly to the three trichotomies described earlier.

With a table similar to that depicted on Figure 4.11(c), Peirce correlated two trichotomies to explore the derivation of classes of decadic signs, as depicted in Figure 4.11(e). Nevertheless, semioticians, who should care about what stands for what, have mostly disregarded the semantics associated with such tables, referring their semantics indiscriminately.

At first glance, the tables in Figures 4.11(c) and (e) seem quite similar, and in fact, they are in their form, but not in their content. The contents of the table in Figure 4.11(c) are trichotomies organized according to a ternary sign relation and the

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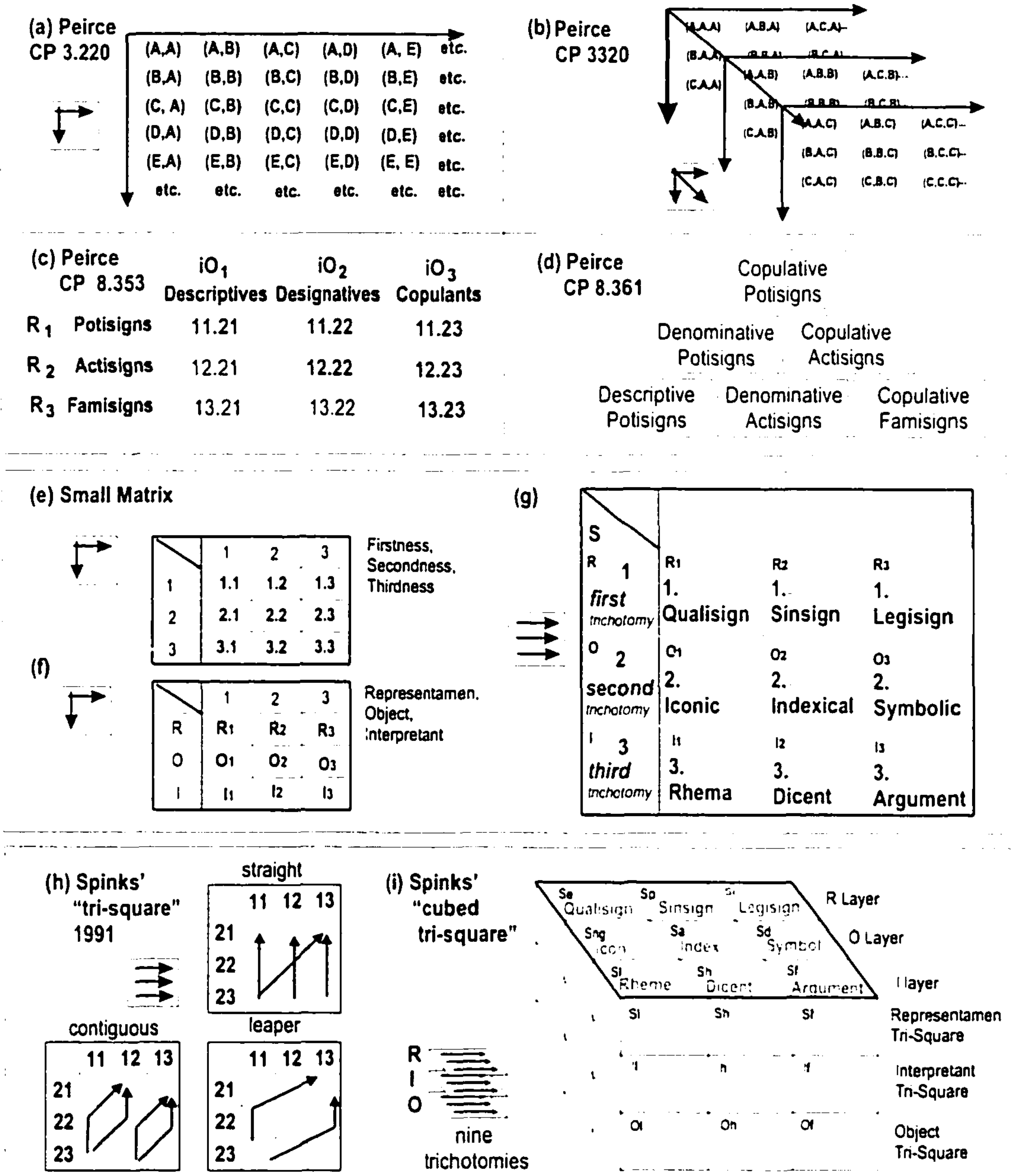
moment. In this framework there is no sense, for example, to affirm that a photograph *is* an icon, an index, or a symbol. It is possible to say, however, that the photograph is in a state of a firstness, secondness, or thirdness, at a certain state of a semiotics process, seen from the perspective that ties representamens and objects. They are relational, not existential categories.

[21] Peirce (1931-1935, 319) relates his Algebra of Relatives with semiotics. He also developed a relational calculus in which he could easily understand the correlation between signs and categories, as mentioned above.

[22] When two sets are correlated with the aid of a table, the elements of each set are used to organize the table's lines and columns. These sets can be the same set. The resulting matrix can represent highways between cities, or a shift timetable which organizes who should be working (people) at what time slot (hour).

[23] In the original illustration, Peirce used $A : B$ to represent (A, B).



(a) Peirce CP 3.220

(A,A)	(A,B)	(A,C)	(A,D)	(A, E)	etc.
(B,A)	(B,B)	(B,C)	(B,D)	(B,E)	etc.
(C, A)	(C,B)	(C,C)	(C,D)	(C,E)	etc.
(D,A)	(D,B)	(D,C)	(D,D)	(D,E)	etc.
(E,A)	(E,B)	(E,C)	(E,D)	(E, E)	etc.
etc.	etc.	etc.	etc.	etc.	etc.

(b) Peirce CP 3320

(c) Peirce CP 8.353

	iO_1 Descriptives	iO_2 Designatives	iO_3 Copulants
R_1 Potisigns	11.21	11.22	11.23
R_2 Actisigns	12.21	12.22	12.23
R_3 Famisigns	13.21	13.22	13.23

(d) Peirce CP 8.361

(e) Small Matrix

	1	2	3
1	1.1	1.2	1.3
2	2.1	2.2	2.3
3	3.1	3.2	3.3

Firstness, Secondness, Thirdness

(f)

	1	2	3
R	R1	R2	R3
O	O1	O2	O3
I	I1	I2	I3

Representamen, Object, Interpretant

(g)

S			
R 1 *first* *trichotomy*	R1 1. Qualisign	R2 1. Sinsign	R3 1. Legisign
O 2 second *trichotomy*	O1 2. Iconic	O2 2. Indexical	O3 2. Symbolic
I 3 *third* *trichotomy*	I1 3. Rhema	I2 3. Dicent	I3 3. Argument

(h) Spinks' "tri-square" 1991

(i) Spinks' "cubed tri-square"

Figure 4.11: **Use of tables to derive categories:** (a) and (b) are based on Peirce's diagram and textual suggestion (Peirce, 1931-1935, 3.220 e 3.320); (c) and (d) are based on Peirce's discussion of decadic signs (Peirce, 1958, 8.353-365) ; (e) Max Bense's small matrix (Walther, 1979, p 58); (f) and (g) are the equivalent tables but in the notation adopted here; (h) and (i) are based on (Spinks, 1991, p 150).

categories of firstness, secondness, and thirdness. The trichotomies in Figure 4.11(e) are not inside the table, but outside, organizing its rows and columns. In it, the contents of the table are the possible dyadic relations between the elements of the two trichotomies.[24] While Peirce was inquiring into the relations between trichotomies already derived, Walther and Bense were generating the trichotomies, which is quite a different thing.

I proceed now with several diagrams found in the literature. The reader will note that the graphical language present in these diagrams differs from that used in informatics. Their authors were mostly semioticians, not people in informatics. Indeed, mathematicians have developed some of the diagrams, but not to the extent of making them adequate to the practices in semiotics and informatics. My objective is to establish a common ground, through a graphical language, to facilitate agreement across professionals both in semiotics and informatics.

Walther and Bense called this the $(R, O, I) \times (1, 2, 3)$ table the "little matrix", and visualized it as in Figure 4.11(e) (Walther, 1979, p 58). Figures 4.11(f) and (g) are equivalent, but I have added information to facilitate their understanding. The tabular representation of the three basic trichotomies has been widely used in semiotics.[25]

As Peirce suggested, ternary relations would be easily correlated with the aid of a cube. However, the same hesitation to fully embrace triadic signs is also found in the lack of use of three-dimensional diagrams to depict the categories of decadic signs. There is no easy way to represent the correlation between three sets with a two-dimensional table. Nevertheless, semioticians have hesitated until recently, to use three-dimensional correlations and three dimensional spaces to depict Peirce's categories.

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[24] These are trichotomies derived from decadic sign relations ($(R_1 R_2 R_3) \times (iO_1 iO_2 iO_3)$, iO stands for immediate object). See Section 4.5 for decadic sign relations.

[25] See also Peirce (1931-1935, 2.233-53) (Weiss and Burks, 1945, p 385), Sanders (1970, p 7), (Deledalle, 1987, p 73), Fisette (1990, p 23), Spinks (1991, p 97), and (Farias and Queiroz, 2000a, p 23), for other diagrams of the ten categories.

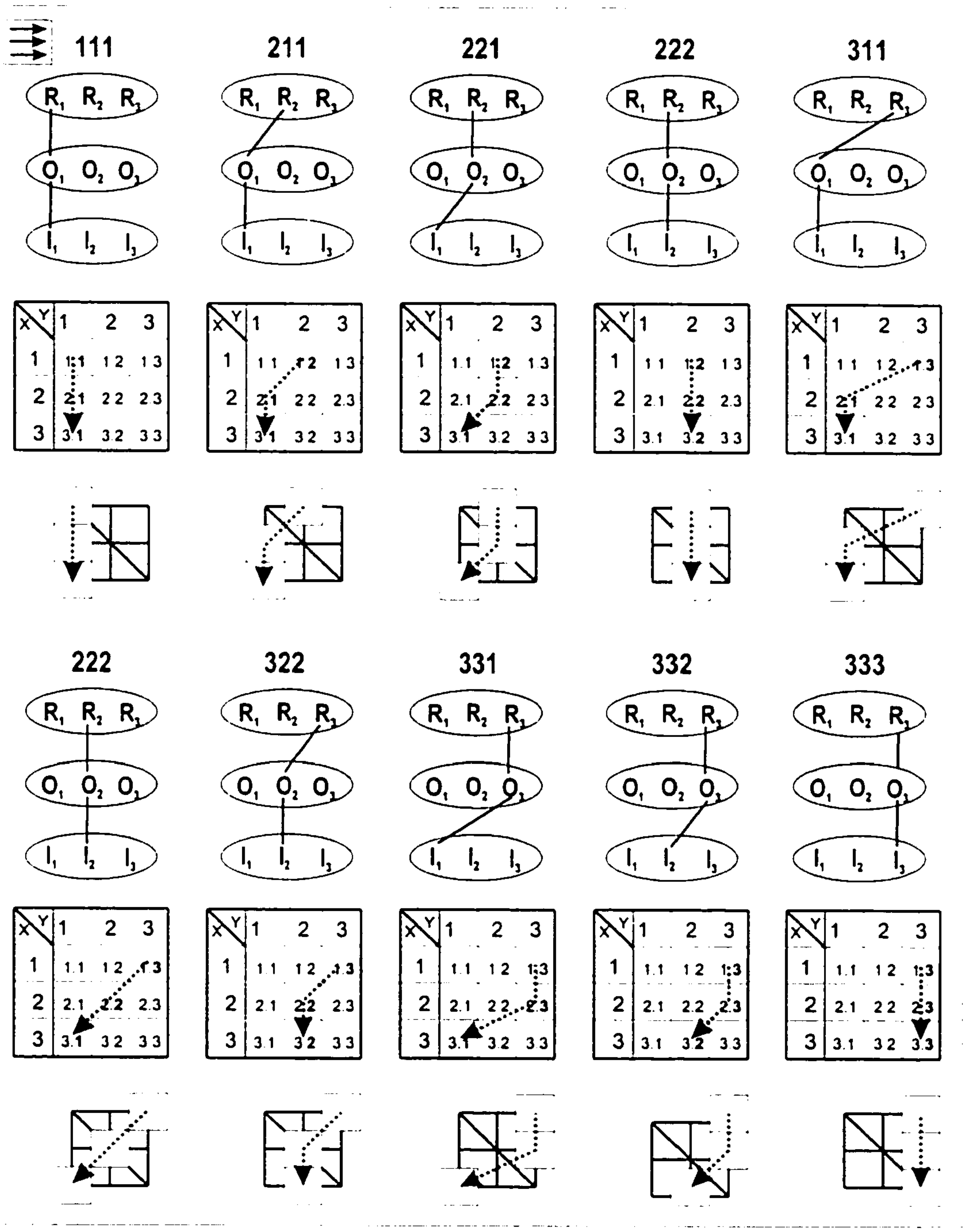

Figure 1.12: **Blomeyer and Helmoholtz's table with the 10 categories:**Based on (Blomeyer and Helmholtz, 1976), cited in (Walther, 1979, p 87)

The solution, frequently found in many different forms, has been to maintain the table representing the three trichotomies, and superimpose onto it a set of links between its cells. Among those who explored this resource to visualize the categories are Blomeyer and Helmholtz (1976), Walther (1979, 80-87, redrawn) (Figure 4.12), Deledalle (1979, p 80-1), Fisette (1990, p 26), Spinks (1991), Merrell (1996, p 94) (Figure 4.13), and Moran (1997), as I comment in the sequel.

Gerald P. Blomeyer and Rita M. Helmholtz, an following them, Elisabeth Walther used a square of arrows to represent the ten classes of signs of a ternary sign relation (Blomeyer and Helmholtz, 1976) cited in (Walther, 1979, p 87). See the ten tables in Figure 4.12. Walther (1979, p 87) grouped the ten categories into four groups called primary, secondary, tertiary and quaternary according to the kind of arrow they form, and presented the groups in four diagrams. These four groups have been separated into ten diagrams and depicted in Figure 4.12. From the mathematical point of view, the use of links between rows (or columns, depending on the diagram) of a table is equivalent to the graphic formalism used to depict relations between sets, as depicted also in Figure 4.12. The sets represent the rows. Only the ten sequences that satisfy prescision have been depicted in Figure 4.12. The sequence $R_2O_2I_1$ satisfies prescision by having the first index larger or equal than the second index, and the second index larger or equal than the third index. $R_1O_2I_1$ for example, does not satisfy prescision because the first element is smaller than the second. Therefore it is not among the ten diagrams.

Using a similar resource, Merrell (1996) juxtaposed all the ternary relations that correspond to the ten categories into a single table, as illustrated in Figure 4.13(a). I have redrawn Merrel's diagram to facilitate comparison with the other ones. In an attempt to simplify the diagram, Merrel cut out the relations in the table in Figure 4.13(b) that are redundant according to Peirce.[26]

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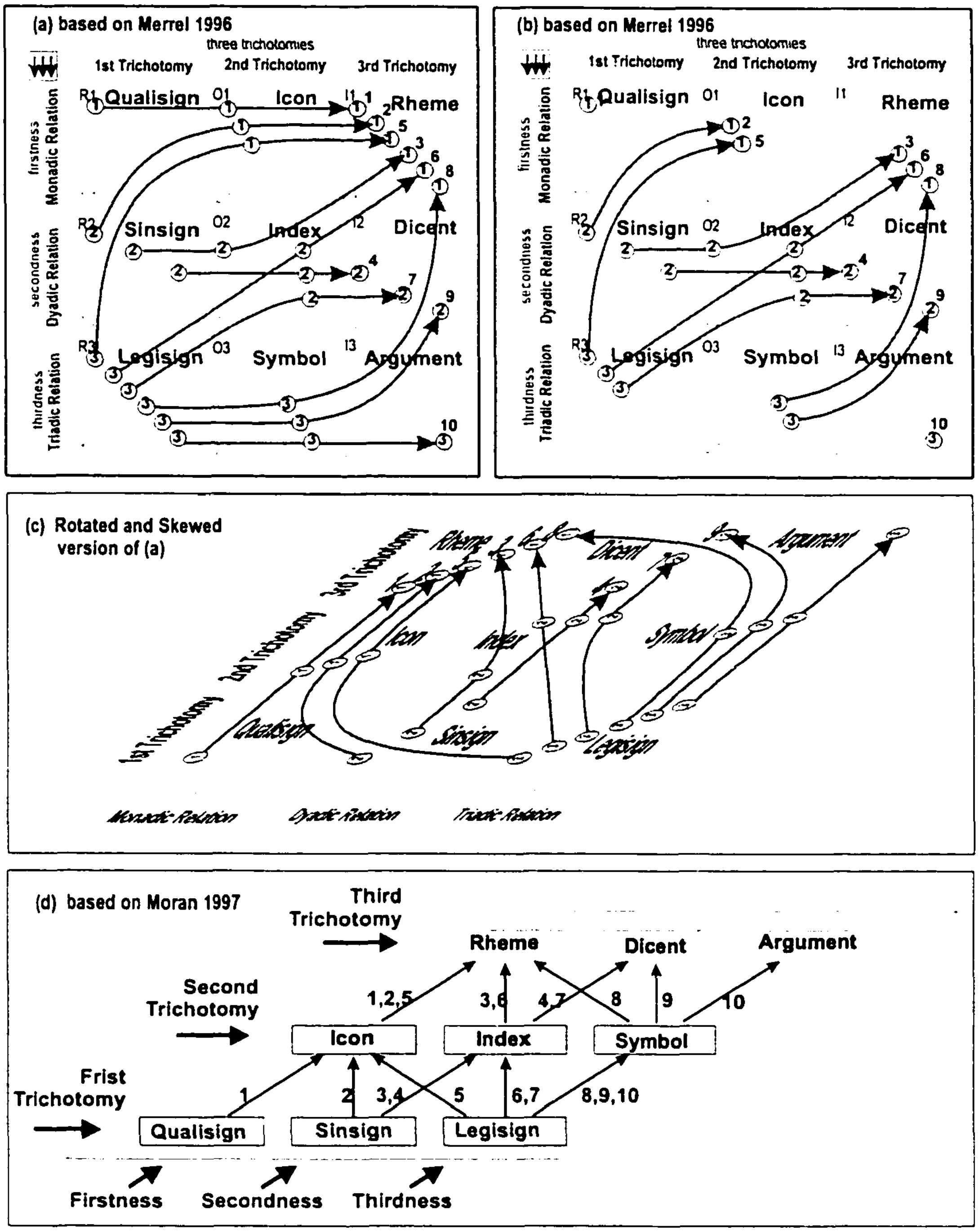
[26] Peirce used this resource to name the ten categories, instead of a Remathic Iconic **Qualisign**, he called it just a Qualisign. For Peirce, or for a Peircean scholar, this may make sense, but for the overall communities, who do not even agree with the order of the sign relation, this is certainly confusing.



(a) based on Merrel 1996

(b) based on Merrel 1996

(c) Rotated and Skewed version of (a)

(d) based on Moran 1997

Figure 4.13: **Merrel's extension of the table of trichotomies** (a) Based on Merrell (1996, p 8) (b) based on Merrell (1996, p 94, redrawn) (c) rotated and skewed (d) based on Moran (1997). The numbers correspond to the categories.

As illustrated in Figure 4.11(g) Spinks (1991, p 150) developed two-dimensional and suggested three-dimensional diagrams that made use of superimposed arrows. Spinks called the three trichotomy table a *tri-square* and also stacked the three trichotomies. Spinks points to Gérard Deledalle as the source of his tri-squares (Deledalle, 1979, p 80-1). When Delledale grouped them using the "largest phaneroschopic category" (firstness, secondness and thirdness) that each class contained (Deledalle, 1979, p 80-81), Spinks grouped them as forming "straight, contiguous, and leaper" traces (Spinks, 1991, p 150). Spinks also staked three tri-squares, extending even further the use of this formalism. He did not attempt to visualize the classes graphically though. Moran (1997), as redrawn in Figure 4.13(c) also used the same resource. The diagram in Figure 4.13(d) is intended to stress the similarities of Merrel's and Moran's solutions, depicting a skewed rotated version of Merrel's diagram. I have not reproduced all the diagrams that I came across that use the above resource.

I now present some solutions found in the specialized literature to visualize the categories with the aid of three-dimensional spaces, containing the three trichotomies of the ternary sign relation.

Michel Balat correlated two and three trichotomies and used two and three dimensional spaces to visualize the ten resulting categories. In the two-dimensional case, as redrawn in Figure 4.14(a) , Balat used the first and the second trichotomies to determine a plane or table in which the categories could be plotted. The limit of having only two dimensions implied that more than one category is represented in some cells of the diagram. Boundaries were added to group the second trichotomy (Balat, 1990). The arrows in the diagram are discussed in the next section and correspond to relations between the categories.

Michel Balat also developed a three-dimensional diagram depicting explicitly the ten classes of signs derived from ternary sign relations, and the relation between them, as in Figure 4.14(b). Balat have not discussed the diagram in Figure 4.14(b) or further explored it in other publications.[27] From the mathematical point of view this

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[27] Personal communication.

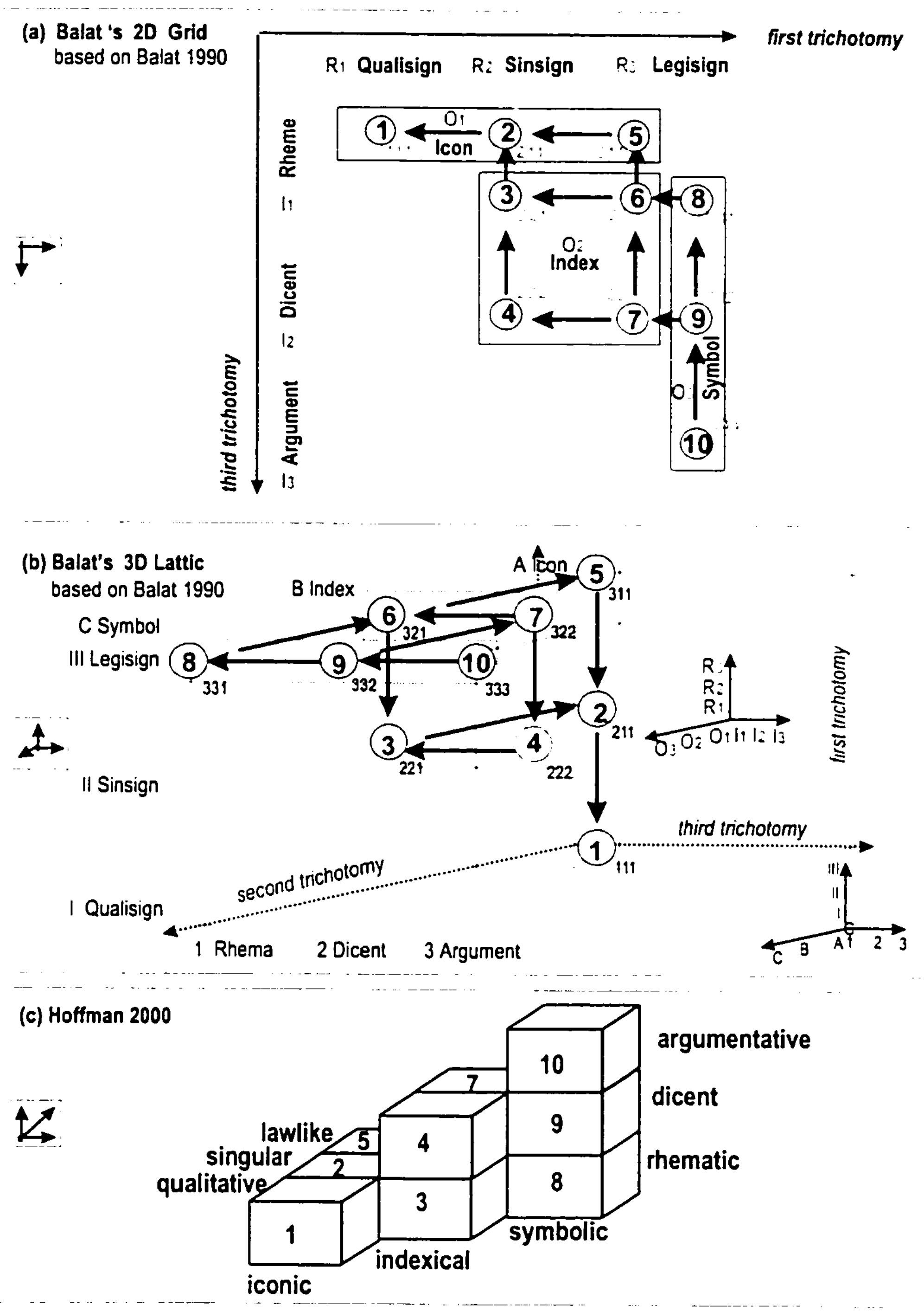

Figure 1.14: **Three dimensional diagrams of the categories:** (a) and (b) based on Balat (1990) (c) based on Hoffman (2000, redrawn)

diagram goes beyond the other two and three-dimensional diagrams presented here by observing the conventions usually adopted in the field. Another difference is that the relations between the derived classes are depicted as arrows. These arrows came from Balat's use of a mathematical structure called a lattice to describe the relations between the ten categories. The arrows in the diagrams correspond to relations of order between the categories, which I discuss in Section 4.4.2. In Figure 4.14(b) I have redrawn Balat's three-dimensional version of the diagram, complementing it with the three rectangles to the two-dimensional diagram, grouping icons, indexes and symbols.

Michael Hoffman has also used cubes to represent the ten classes, as shown in Figure 4.14(c) (Hoffman, 2000). He did not represent axes or relations, however.

Priscila Farias and João Queiroz have used differently colored cubes in a three dimensional space to represent the ten categories, as shown in Figure 4.15 (Farias and Queiroz, 2000a, p.36-41). They also developed a computer application to visualize ten colored cubes within the 2D representation of three-dimensional space. The diagram on the left of Figure 4.15(a) is a chosen projection of the ten categories. These authors have used a different convention than the ones usually adopted to visualize vectors and planes in three dimensions.[28]

Except for Peirce's and Balat's diagrams, most of the diagrams discussed until now do not explicitly represent the relations between the derived classes.[29] In the sub-

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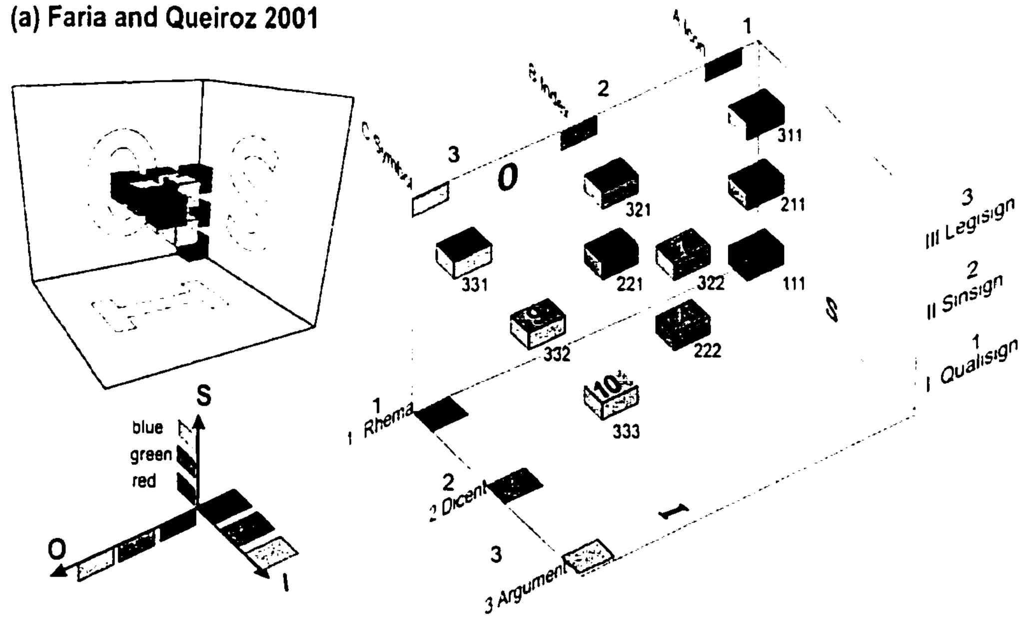
[28] In linear algebra, another branch of mathematics that works with vectors, a standard way of defining a plane is with a vector normal to it. In the upper left corner of Figure 4.15(b) there is a small cube illustrating the orientation of the faces of a parallelepiped. In linear algebra the same mechanism is widely used to describe planes in general. The product of two vectors with different orientations determines a third vector orthogonal to them. Farias and Queiroz are using a different convention to label the planes S, O, and I, as in Figure 4.15(a). What they label S is a plane defined by the axes (S and I). Therefore, the plane S contains the axis defined by the first trichotomy. What they labeled O, is a plane defined by (O and I). What they labeled I is a plane defined by axes O and I. See Section 4.4.1 for more on coordinate systems.

[29] In a diagram not shown, Farias and Queiroz (2000a, p.39-40) depict relations of instantiation and involvement through the simultaneous representations of cubes of different sizes in the volumetric space (larger cubes contain smaller ones.) The relation needs to be inferred by the observer because


(a) Faria and Queiroz 2001

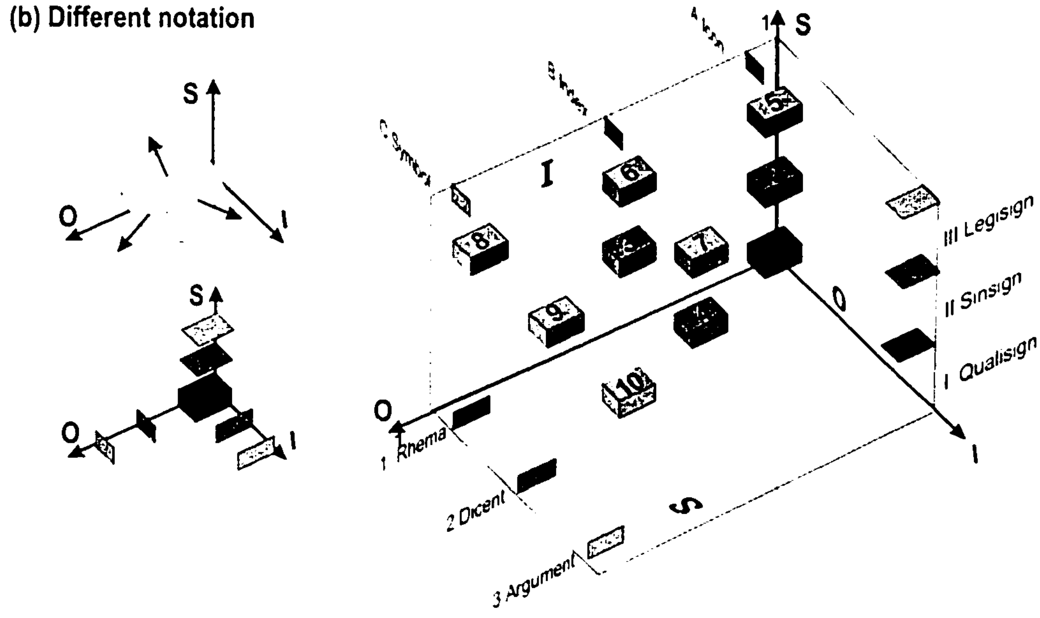

(b) Different notation

Figure 4.15: **Farias and Queiroz's 3-dimensional diagram of the ten classes:** (Farias and Queiroz, 2000a, p 36-41).

sequent section. I discuss the literature in which the relations between the categories have been the foci and the proposed corresponding diagrams. Before proceeding, it is necessary to present some conceptual tools that I use to analyze and visualize the relations between derived classes.

4.4.1 Partially Ordered Sets and Spaces

The use of the term lattice has not been uniform in the specialized semiotic literature. Some have used it in the mathematical sense that I describe in the sequel, while others have construed it simply as a grid.[30]. In mathematics a lattice is a special kind of a *partially ordered set*, or *poset*.

A set is partially ordered when it is possible to compare all of its elements according to a certain criterion. The important factor is that the elements can be compared, rather than the outcome of the comparison, that does not need to be a strictly ordered set. For example, it is possible to compare a set of names, written in the same alphabet, and organize them in alphabetical order, as illustrated on the left of Figure 4.16. A set containing names represented Latin alphabet and kanji ideograms is not partially ordered because there is no criteria to compare all the elements.

A partially ordered set, or poset, implies a relation of order, but not necessarily a linear order. In a linear order, one element is after the other, as in a chain. Chains are a special case of partially ordered sets, as lines are special cases of planes. The sequence of integers (1, 2, 3, 4, 5) is such a chain, and it is organized under the relation of "magnitude comparison"(Preparata and Yeh, 1974, p 184). If there were two or more individuals with the same name, the names continue to be comparable alphabetically, but a name may have two or more immediate successors, as illustrated on

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the relation is not depicted directly in the diagram. The use of Hasse diagrams, as I explore in a subsequent section provides a different solution.

[30] For a formal definition, the reader should follow the specialized literature. For example, for a short introduction, see Preparata and Yeh (1974, p 184-215), Doughrty and Giardina (1988, 71-77), and the chapters on lattices contained in Birkhoff and Bartee (1970). For an in-depth study see Birkhoff (1967)

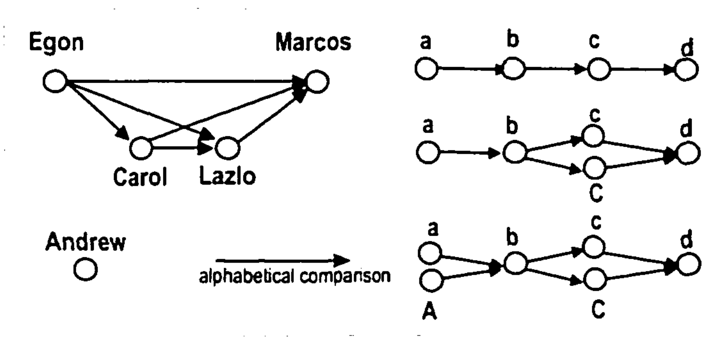

Figure 4.16: **Examples of partially ordered sets (posets)**

the right of Figure 4.16 with the aid of letters.

This is the case of Peirce's sign relations and their derived categories. In Peirce's derived categories, whatever their cardinality {3, 6, 10, 28, 66, ...}, there is always a way of comparing two categories. The understanding of the categories as a partial order is interesting because the order emphasizes the categories' dynamic nature. When a sign (e.g. a sketch) that is only a possibility (firstness), for example, becomes an existent (e.g. model, prototype) through action (e.g. design, secondness), and later on becomes a blueprint (thirdness) through repetition (habit) for other signs, it is the traversal of the categories that is important, not their isolated characteristics which are usually used to classify them.

In a poset, an element a is the *immediate predecessor* of an element b if there is no element c between them. In an alphabetically ordered poset, this means that the immediate predecessors of a name are those that come immediately before them, but having no names in between. The inverse comparison (or relation) is the *immediate successor*. A poset can also be understood as a simplified network of elements. The links between the nodes/elements represent the relations of order between them.

A Hasse diagram is a standard graphical notation used for representing partially ordered sets. Hasse diagrams are interesting because they visually simplify the representation of partially ordered sets without loss of information. The importance of Hasse diagrams for the representation of Peirce's multiple categories is that the number of links can be reduced, but not the information contained in the diagram.[31]

To derive a Hasse diagram of a partially ordered set, the following steps illustrates in Figure 4.17 need to be followed:

1. A first step is to eliminate the arrows that point to the nodes themselves. This can be done because any element can always be compared to itself.
2. A second step is to draw the graph or network assuming that the relation of order is depicted vertically. The nodes that have no predecessors are represented lowest on the page and the nodes with no successors, highest. It is recommended to start at the extremities and to restructure the diagram incrementally, considering subsequent successors (or predecessors).
3. The vertical placement of the nodes imply their relative order, therefore the arrows in the links can be eliminated. There are cases, though, where it is interesting to maintain them.
4. A third and last step eliminates the links between nodes that are not immediate predecessors. To know if a node succeeds another one it is necessary to see if there is a path between them.

The process to derive a Hasse diagram from a graph representing a poset is described in Figure 4.17. Figure 4.17(a) depicts on the set $\{1, 2, 3, 4, 6, 8, 12\}$ under the relation of divisibility. 8 is divisible by 2, for example, therefore there is an arrow going from 2 to 8, etc. Every number divides itself, so there are arrows that start and end at the same nodes.

The orientations of diagrams as graphs, or of their arrows, should not be used to say that one diagram is different from another one, without an analysis of the adopted conventions of each. This is a common misunderstanding found in the semiotic literature.

This is a weak definition, but for a poset to be a lattice it is necessary that any two elements have a unique join (sum) and meet (product). A stronger definition has

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[31] I suggest later that the simultaneous use of Hasse diagrams and coordinate systems to aid the representation of Peirce's categories.

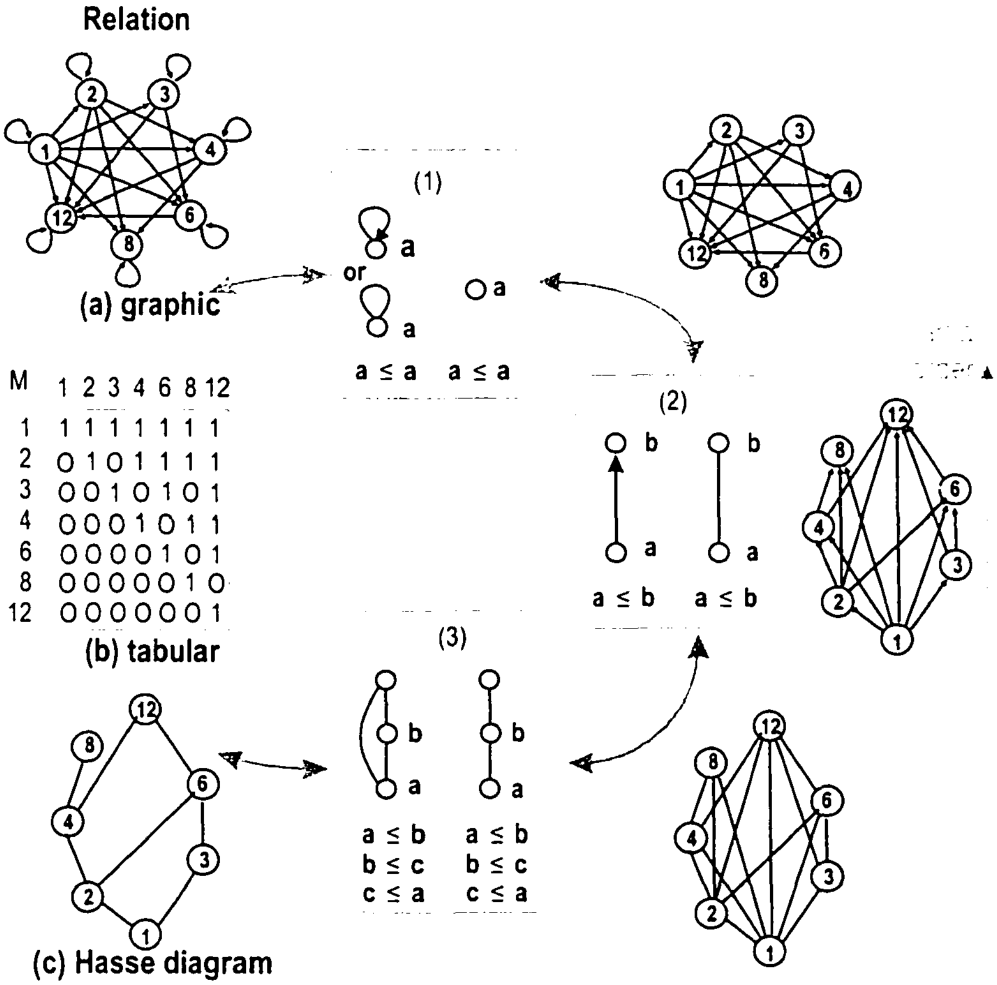

Figure 1.17: **Process of construction of a poset's Hasse diagram** The process starts with a graph depicting the relation of order of the poset. In this case it is a relation of divisibility. (1) Eliminate links that start and end at the same nodes (2) Redraw the diagram assuming the partial order. In the example, number 1 divides all other elements so it is represented at the bottom. Accordingly, 12 is represented at the top. The arrows can be eliminated because the vertical position of each note represents their order. (3) Eliminate links that are not between immediate predecessors. In the example, the link between 8 and 2 can be eliminated. It is still possible to know that 8 is divisible by 2 by following the path through number 4.

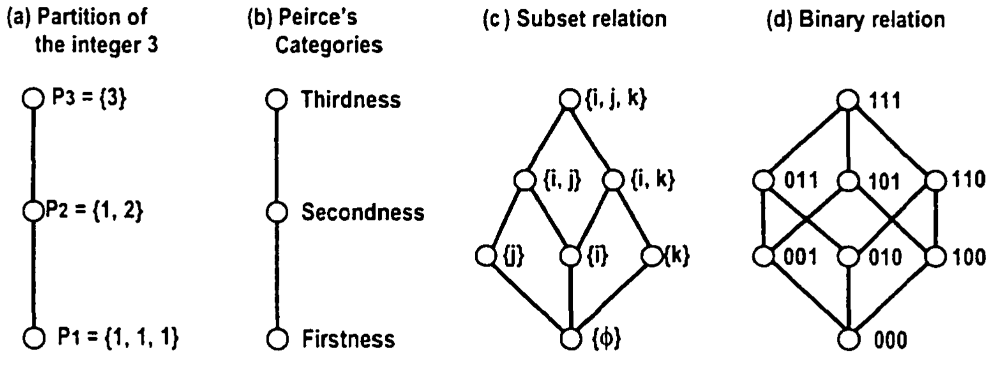

Figure 4.18: **Example of lattices:** Lattices under partial orders related to: (a) partition (b) Peirce's categories (c) subset relation (d) magnitude

to do with the presence in a finite poset of a least upper bound and a greatest lower bound. In the Hasse diagram, this means that following the path starting from two nodes, the paths will cross above the nodes (join or sum) and below (meet or product) at some point. Figure 4.18 represents the Hasse Diagrams of some posets that are lattices. Peirce's categories are lattices, in the mathematical sense. In Peirce's ten categories, the nodes $R_1O_1I_1$ and the $R_3O_3I_3$, being the greatest lower bound and the least upper bound, respectively, would be represented lower and higher than all the other nodes.

The graphical orientation of the links between immediate predecessors in a Hasse diagram is the only constraint used to represent the elements of the poset and their relations. In this sense the same partially ordered set can be represented in multiple forms and arrangements. The important factor is that a path should connect two nodes if they are related. Figure 4.19 illustrates three possible ways of representing the same lattice. They are all equivalent.

Another example of a special lattice is a projective geometry. In mathematics spaces may have multiple dimensions, as illustrated in Figure 4.20(a). For example a volume has three dimensions. An n-dimensional space includes other sub-spaces with lower dimensions than n. For example, volumes contain planes and points. The representation of geometric figures on paper demands a certain projection of its

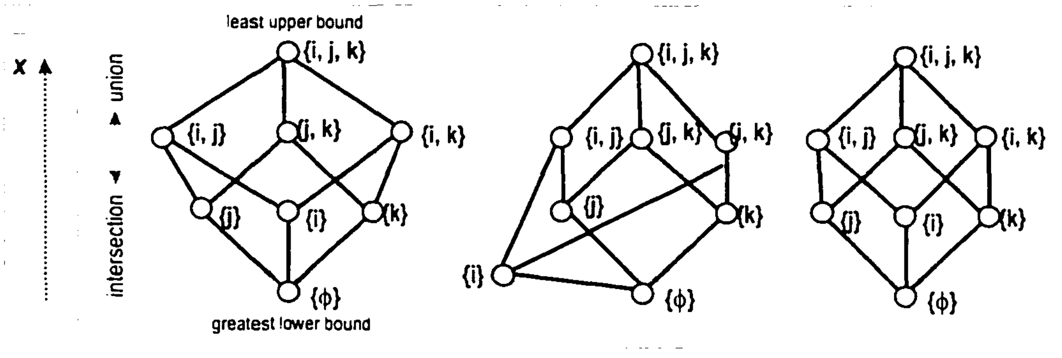

Figure 4.19: **Hasse Diagrams organized through one dimension** The x-axis in the figure is associated with direction in which *joins* between two elements of the partially ordered set are represented. For example, the union between the sets i and j results in the set $\{i, j\}$, which is represented above them. Their intersection, the empty set 0 is represented below them. The relative position of $\{i, j\}$ and $\{j, k\}$, in this example cannot be compared because their is no relation of inclusion between them. They have a unique join $\{i, j, k\}$ and a unique meet $\{j\}$ which correspond to their union and intersection, respectively. All three Hasse diagrams are valid representations of the same poset.

three-dimensional elements onto the 2-dimensional surface of the paper.

The lattices represented in Figure 4.20 take into consideration the representation of the spaces which they form. In this sense, additional dimensions are used to organize the diagram, instead of the single one usually used in Hasse diagrams. As I have shown in the preceding section, several authors have proposed representations for Peirce's ten categories that use three-dimensional spaces.[32] In the sequel, I propose that the simultaneous use of Hasse diagrams and geometric projections within Cartesian coordinate systems can represent Peirce's categories.[33]

Considering that not everybody is well-versed in three-dimensional representa-

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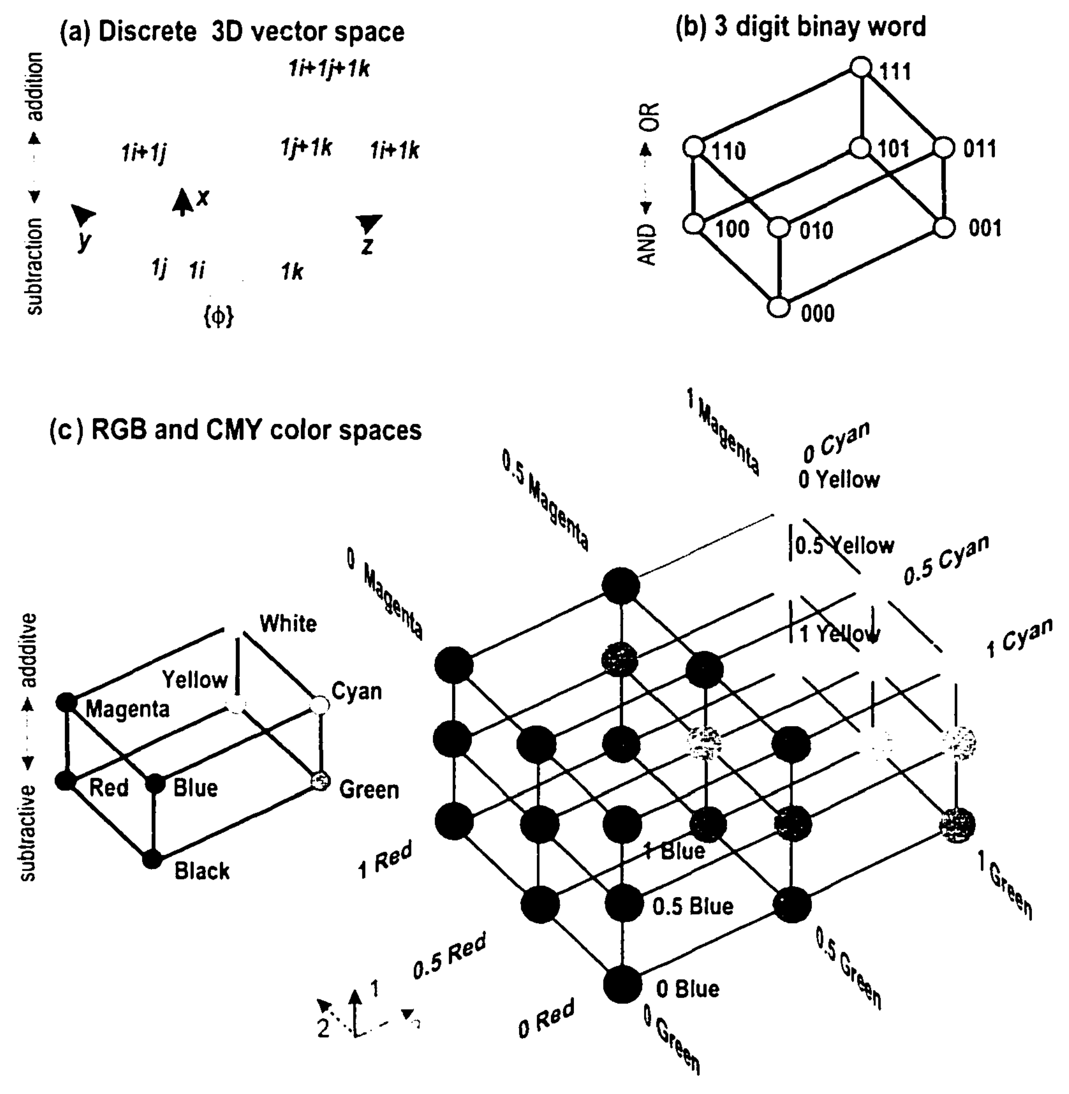
[32] The three-dimensional representation of Peirce's ten categories has been explored by Balat (1990), Hoffman (2000), and Farias and Queiroz (2000a, p 36-41). Respectively, these representation have been reproduced in Figure 4.14(b), Figure 4.14(c), and Figure 4.15(a).

[33] For certain lattices, it is possible to plot the elements of the poset in such a projection that they do not coincide on the two dimensional surface of the page, as it happened in the diagrams depicted in Figure 4.14(c) and in Figure 4.15(a).


(a) Discrete 3D vector space

(b) 3 digit binay word

(c) RGB and CMY color spaces

Figure 1.20: **Hasse Diagrams organized through three dimensions:** (a) Vectors of finite length can be added or subtracted (b) In a Boolean algebra it is possible to realize AND and OR operations between two binary digit words (c) A color space in which colors are added (RGB, light) or subtracted (CMY, pigment) operations can also be understood as a lattice.

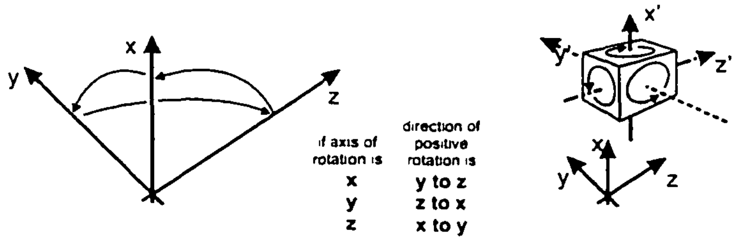


Figure 1.21: **Cartesian left handed coordinate systems:** A point in a three-dimensional coordinate system is described by three coordinates. Orientation in a three-dimensional space is described by three angles.

tions. I briefly introduce Cartesian Coordinate Systems and their associated conventions. Cartesian coordinate systems provide a graphical alternative to visualize the same constraint associated with prescision. There are several conventions used to represent three-dimensional Cartesian coordinates on a two-dimensional surface. The straightforward ones mainly differ on the angle, on the placements of the axes and on the orientation of rotations. Figure 1.21 illustrates a Cartesian left handed coordinate system.[34]

In cartography there are several kinds of projections to describe surfaces. There are several methods to describe planes and volumes. As illustrated in Figure 1.22, an infinite band parallel to one of the planes determined by two of the three axes is determined by constraints on the coordinates. For example, a set of simultaneous restrictions such as $x \geq x_1$ and $x \leq x_3$ determines an infinite band such as the one represented on the upper left corner of this figure.

Figure 1.23 illustrates how to represent a rectilinear parallelepiped. First the faces are defined as special cases of larger planes formed by two axes. Three intervals such as $x_1 \leq x \leq x_2$, $y_1 \leq y \leq y_2$, and $z_1 \leq z \leq z_2$ determine a parallelepipedal space. The shaded regions indicate the valid intervals. The intersection of all the restrictions

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[34] It is called *left handed* because aligning the left hand's thumb in the positive direction of the axis around which a rotation is done, the fingers point in the direction in which the rotation is positive. It does not matter in which angle the axes are drawn.

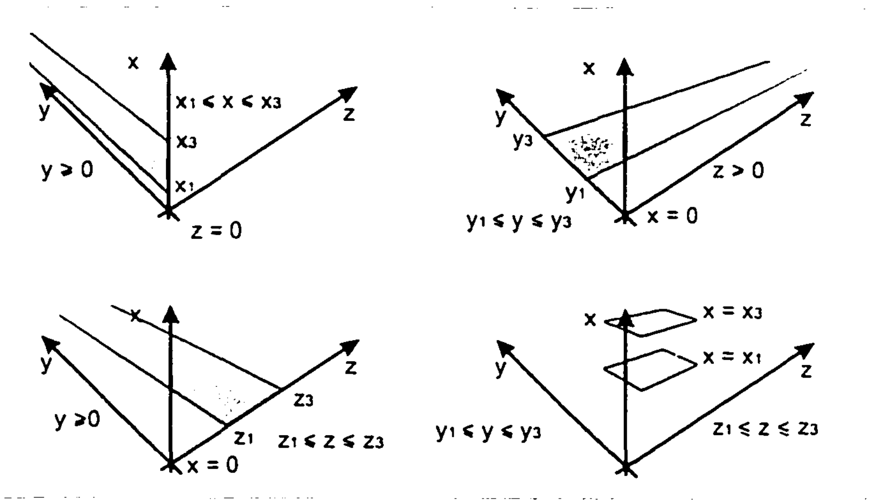


Figure 1.22: **Use of constraints to define regions across spaces**

on the three axes delimit a parallelepiped.

A point on a line, a line on a plane, and a plane in a volume may be used to cut the line, the plane and the volume in two. If one says that in a plane defined by the axes x and y, the valid interval is the one determined by $x \leq y$, the valid region is in between the x-axis and a line between it and the y-axis. See Figure 1.24.

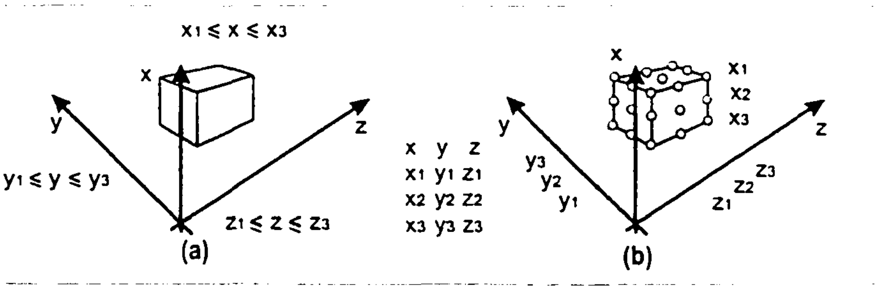
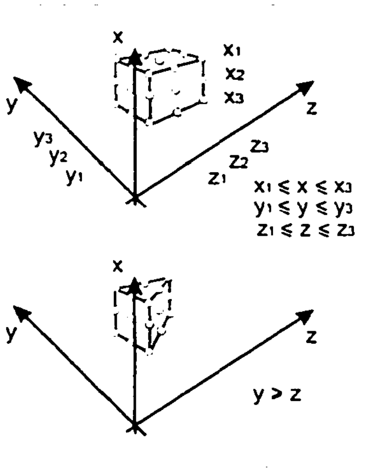


Figure 1.23: **Use of constraints to delimit volumes across spaces**

The space does not need to be continuous. It can be discrete. The twenty-seven points of the discrete parallelepiped represented in Figure 1.24 are reduced to only eighteen when the parallelepiped is cut in half parallelepiped by a diagonal plane between two opposing edges. It is interesting to remark that although the enclosed volume is reduced to half of its original size, the number of points is not.[35]



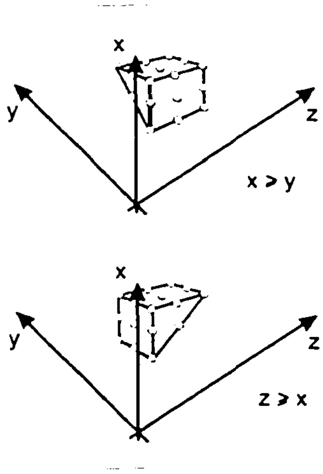


Figure 4.24: **Use of constraints to cut surfaces and volumes across spaces**

Figure 4.25 illustrates the above restrictions in a single plane with nine points (a), and on a volume with 27 points (b). Figure 4.26 shows all the ten points in relation to the twenty-seven in three projections to facilitate the visualization.

In the beginning of this chapter I have used trees and tables to illustrate why there are only ten categories of signs among the twenty-seven possible combinations. My intention with the above geometrical constraints, and corresponding visualizations, is to aid an in-depth understanding of Peirce's categories. [36]

Each of the three trichotomies could be represented by an axis of the system. The x, y, and z axes correspond to the representamen, the object, and the interpretant, respectively. The three projections cut slices through the solid. In accordance with the notation usually adopted in semiotics, I used the numbers 1, 2 and 3 to represent firstness, secondness, and thirdness, respectively. Following the standard way of

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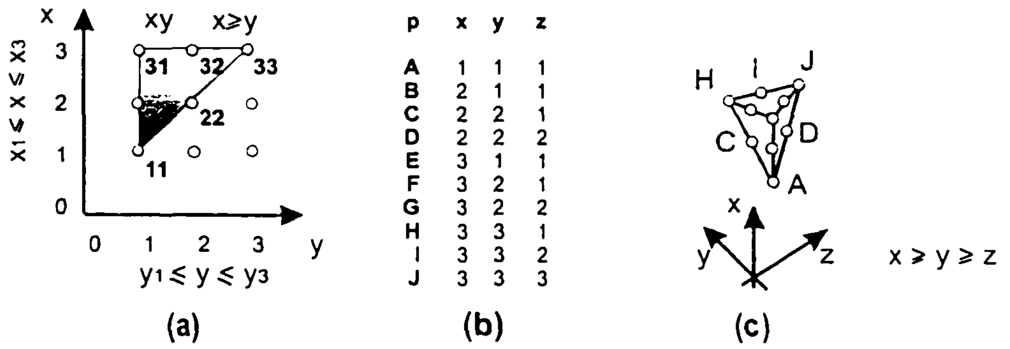
[35] In the case of difficulties to visualize these constraints, I suggest that the reader take a small box like a drug package and draw points an each vertex and in the middle of each side. Don't forget that there is an additional point at the center of the box. With different cuts, count the points.

[36] See Figure 4.11 for an illustrative example of an homologous restriction given by Peirce to explore possible relations between trichotomies.



p	x	y	z
A	1	1	1
B	2	1	1
C	2	2	1
D	2	2	2
E	3	1	1
F	3	2	1
G	3	2	2
H	3	3	1
I	3	3	2
J	3	3	3

Figure 4.25: **10 points among 27 of a $3 \times 3 \times 3$ grid of points** The constraint $x \geq y$ and $y \geq z$ selects only ten points within a three-dimensional grid of twenty-seven points.

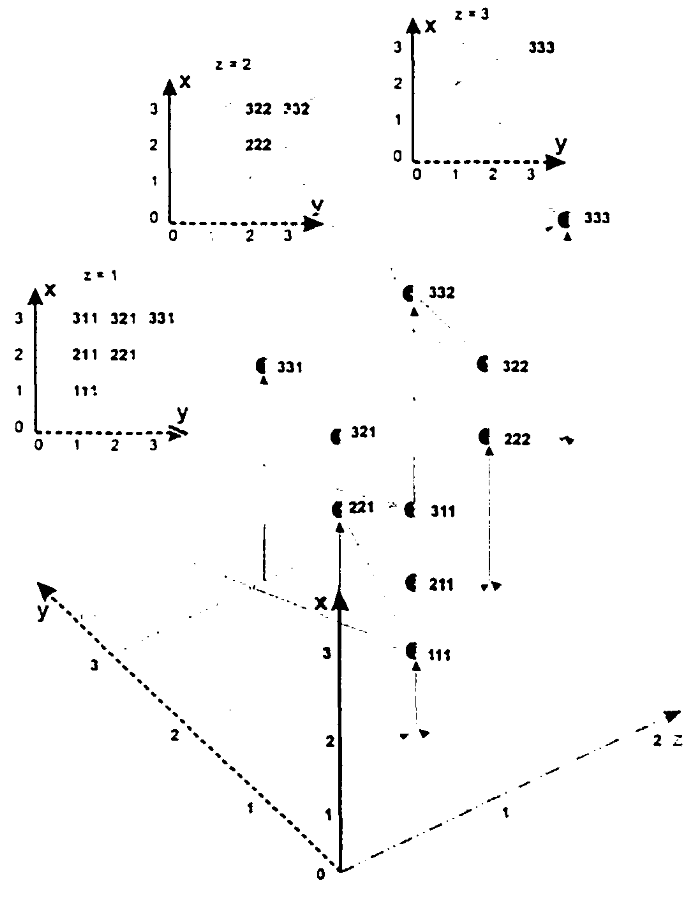


Figure 4.26: **The 10 points in detail**

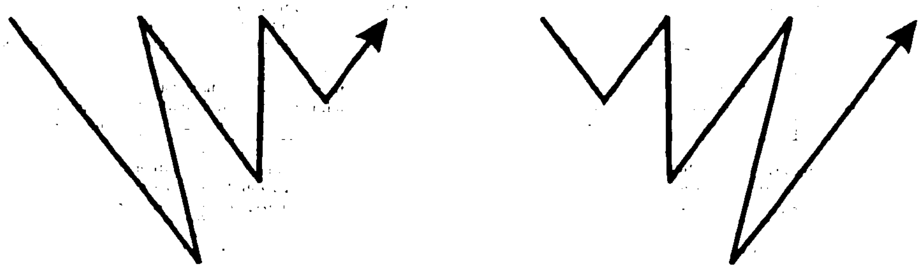
reading coordinates in Cartesian coordinate systems, the three slices in Figure 4.26 correspond to Interpretant planes that include categories as firsts, as seconds, and as thirds. Therefore, the slices group the categories that include at most either Rhemas, or Dicents, or Arguments, accordingly. Planes defined by vectors using other elements of the sign relation group the categories differently. Returning to relations between categories, arguments include dicents that include rhemas. I proceed with a discussion of the literature that discusses relations between categories.

4.4.2 Relations of Order among Categories of Signs

In this section I initially discuss the relations of order among the ten classes of signs and their graphical representations as developed in the literature. I start with Peirce's own explicit representation of the ten categories and their relations, as depicted in Figure 4.8. The ten classes are described as ten juxtaposed rectangles. Peirce used the thickness of the boundaries between two adjacent blocks to depict the affinities (relations) between the classes they denote, enabling an easy recognition of the differences between them (Peirce, 1931-1935, 2.236). Peirce described the relations among classes as:

> "The affinities of the ten classes are exhibited by arranging their designations in the triangular table [shown in Figure 4.8], which has heavy boundaries between adjacent squares that are appropriated to classes alike in only one respect. All other adjacent squares pertain to classes alike in two respects. Squares not adjacent pertain to classes alike in one respect only, except that each of the three squares of the vertices of the triangle pertains to a class differing in all three respects from the classes to which the squares along the opposite side of the triangle are appropriated. The lightly printed designations are superfluous." (Peirce, 1931-1935, 2.264).

From a relational point of view, the order in which the categories are listed does not change the actual set of mutual relations. It only reinforces certain contrasts. Moreover, the textual order in which Peirce listed the ten categories derived from the ternary sign relation varies across his writings. Figure 4.27(a) illustrates the numbered order as in (Peirce, 1958, 8.341), and Figure 4.27(b) illustrates the textual


(a) 2.254

(b) 8.341

Figure 4.27: **Peirce's Categories Lists**

order as in a letter to Lady Welby (Peirce, 1931-1935, 2.254-64). The former is the one of the roman numerals that numbers the ten categories in Peirce's triangular table reproduced in Figure 4.8. However, Peirce's terminology did not vary. I am making this remark to stress that the order in which Peirce listed the components of a sign relation is not a derivation principle. In my understanding, they are just a different way of traversing the categories' poset.

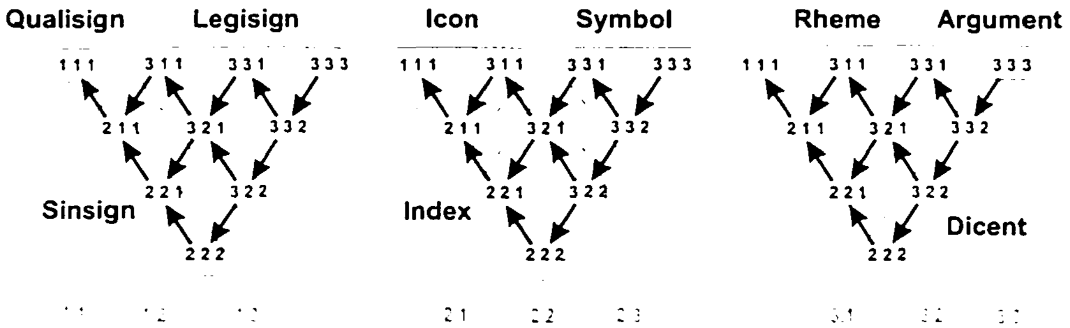


Figure 4.28: **Three trichotomies grouping the ten classes**

Similarly, there are several forms of grouping the categories into distinct subsets. For example, Peirce's three trichotomies of sign relation can be used to group the rectangles in the "triangular table" in three different ways, as shown in Figure 4.28.[37]

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[37] The arrows in Figure 4.28 indicate the transformations in one respect necessary to go from one class to another. It is possible to note that the darker borders are not crossed, for example, because

These orders or groups do not reflect the relations of presuppositions among them. For example, there are links between category VI ($R_3O_2I_1$) and both VII ($R_3O_2I_2$) and the VIII ($R_3O_3I_1$). Category VI differs in only one respect in relation to categories VII and VIII.

A set of relations between the categories can be represented as a network of morphisms, as depicted in Figure 4.29. Mihai Nadin (1979) developed this network. The set of morphisms between categories resembles Peirce's triangular table, which I added to the background to facilitate the parallel. The arrows indicate the transition from possible to real (α), from real to necessary (β), or from necessary to real (β^*), denoting the relations between firstness, secondness, and thirdness across two categories.[38]

Floyd Merrel developed another form of depicting the relations between the ten categories, as depicted in Figure 4.29(b). From a mathematical point of view, Merrel used the same visual formalism so characteristic of Venn diagrams to illustrate the relations of presupposition between the ten categories (Merrel, 1997, p 206, redrawn).[39] In Figure 4.29(b), for example, the tenth category presupposes all the others; the seventh and the eight both presuppose the sixth; the sixth presupposes the fifth and the third, and so on.

Robert Marty developed an in-depth study of the relations between several sets of Peirce's categories with the aid of mathematical lattices (Marty, 1982). In Figure 4.30 (a) I have represented the overall shape of Marty's diagram representing the ten categories and their relations. I have reintroduced Numbers from 1 to 10 in Figure 4.30(a) despite Marty's comment that the order is already represented in the lattice's hier-

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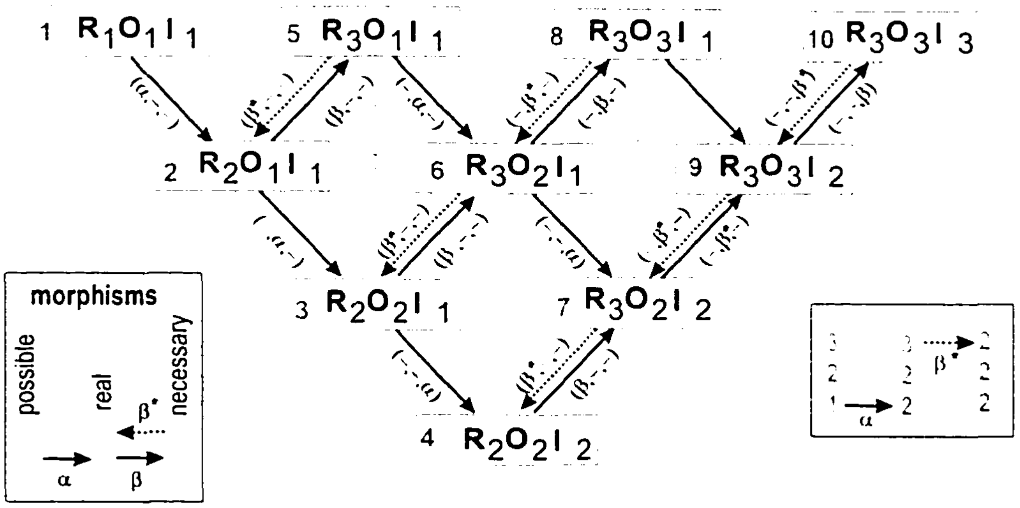
they indicate transformations in two respects.

[38] In Nadin's network (Figure 4.29(a)), the morphisms represented by solid arrows represented a transition from the possible to the real, and from the real to the necessary. Relations of presupposition are denoted by the inverse relation, that the necessary presupposes the real, and the real presupposes the possible.

[39] Venn Diagrams are widely used in Set Theory to illustrate relations among sets. In the same publication Merrel also uses Peirce's existential graphs, which is a different formalism, without clearly demarcating each notation.

(a) Nadin 1979



(b) Merrel 1997

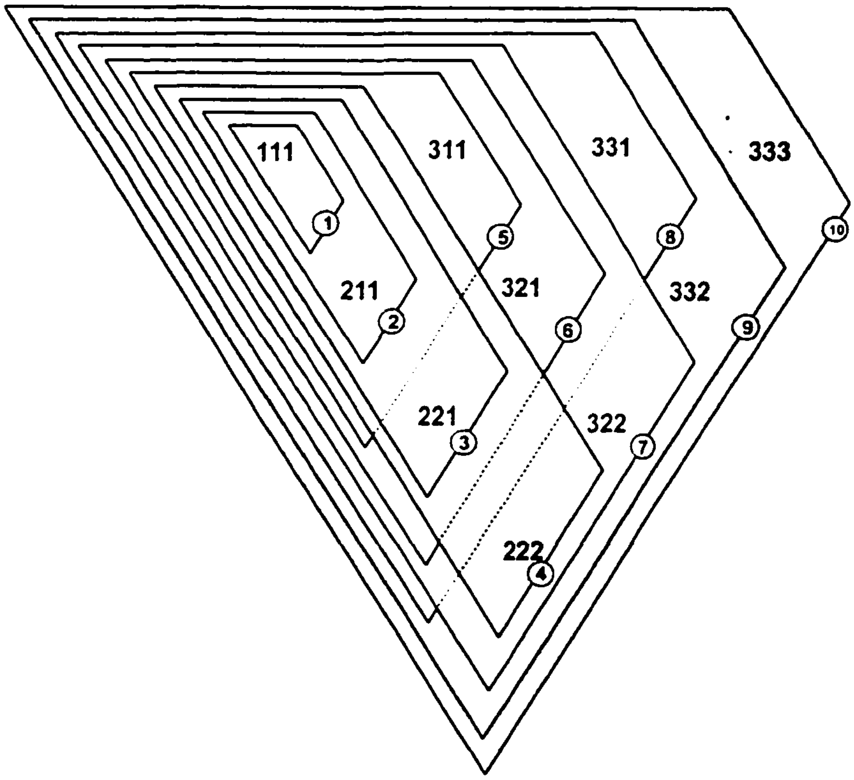


Figure 1.29: **Relations among the ten categories: Nadin and Merrel** (a) Morphisms among categories (Nadin, 1979, p 205, redrawn) (b) Venn diagrams depicting presupposition among categories (Merrel, 1997, p 206)

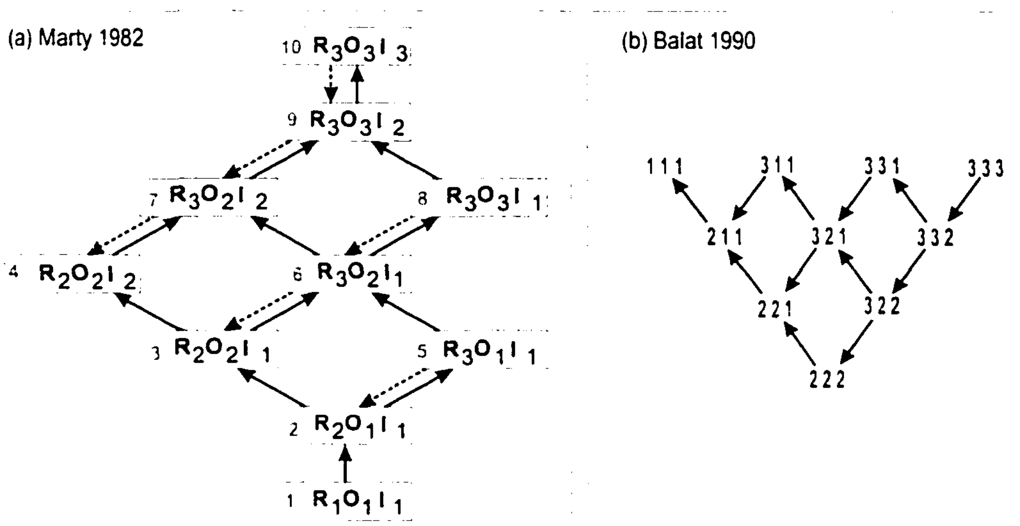


Figure 1.30: **Lattices of the ten categories** (a) based on (Marty, 1982, p 178) (b) based on (Balat, 1990, p 86).

archy.[10] Similar to Marty and Nadin, Michel Balat illustrated the relations among categories with a diagram s similar to the ones depicted in Figure 1.30(a).

The spatial orientations used to organize the several lattices above do not coincide though. While Marty adopted the mathematical convention used in Hasse diagrams of representing *part of* relations, the orientation of Balat's diagram coincides with Peirce's Triangular blocks, as suggested in Figure 1.8. This is not a problem, as long as the spatial relationship is not used to differentiate the categories themselves. The graphical orientation of the diagram is a matter of convention and does not differentiate two diagrams with respect to what they represent.

I now introduce now a visualization of Peirce's categories as a three-dimensional Hasse diagram. Figure 1.31 illustrates a particular projection developed in consonance with the discussion presented until now. The chosen projection of Figure 1.31 is not fortuitous. I have chosen the axes and coordinates to render possible the visualization of all the 27 points of a 3 × 3 × 3 grid regularly spaced, and denoting a unique point in the diagram. I have chosen a parallel projection in order to facilitate

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[10] See Marty (1990, p 171-182) for the introduction of his model and for a detailed discussion of sets with ten and twenty-eight derived categories.

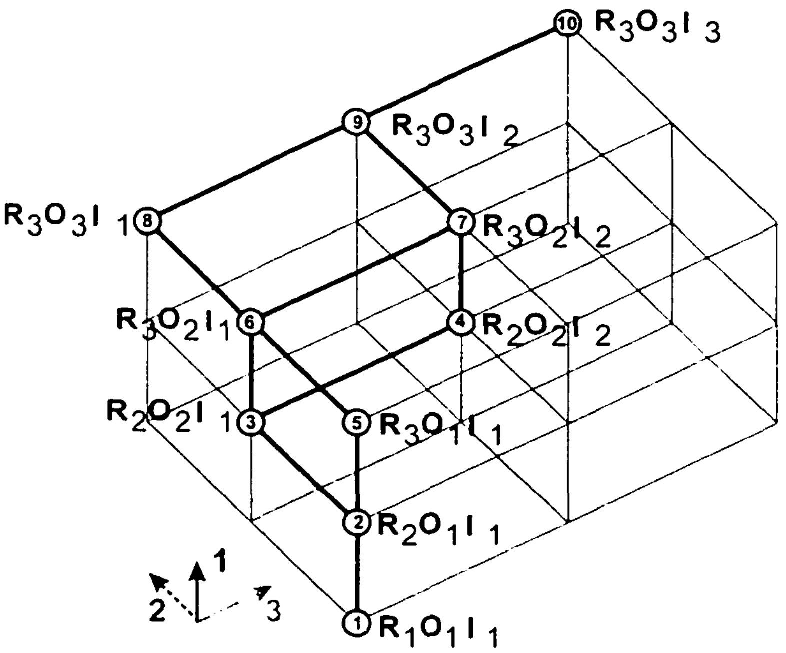


Figure 4.31: **Hasse diagram of the ten categories of ternary sign relations**

its reproduction by hand, an important issue for the diffusion of the diagram across the community.

The edges linking the twenty-seven points do not coincide, meaning that the relations between the ten "valid" coordinates, which can be mapped onto the ten categories, can be explicitly represented without ambiguity. Second, the vertical partial order in which the respective points are drawn is homologous to the one used to depict Hasse diagrams of the ten categories I discussed in the preceding sections. In addition, the chosen projection observes the convention used to represent coordinate systems, as well as the convention used to draw Hasse diagrams.

In Figure 4.31, category $R_1O_1I_1$ (rhematic iconic **qualisign**) is the lowest category in the poset, which implies that all other categories contain it. Category $R_3O_3I_3$ (**argument** symbolic legisign) is at the top of the Hasse diagram, implying that it presupposes all the other categories. I numbered the categories according to the Roman numeral used by Peirce.

Considering what a lattice is and how the conventions of Hasse diagrams have been established, it is not necessary to use ten diagrams to depict the ten categories. This would be superfluous because a single diagram already shows the positions of the categories, as well as their relationships. One of the advantages of using Cartesian coordinates in association with Hasse diagrams to represent the categories is that there is an inherent continuity in the representation, despite its discrete nature. Peirce questioned the stratification of the cenopythagorean categories (firstness, secondness, and thirdness) describing them as "rather tones or tints upon conceptions" (Peirce, 1931-1935, CP 1.353).

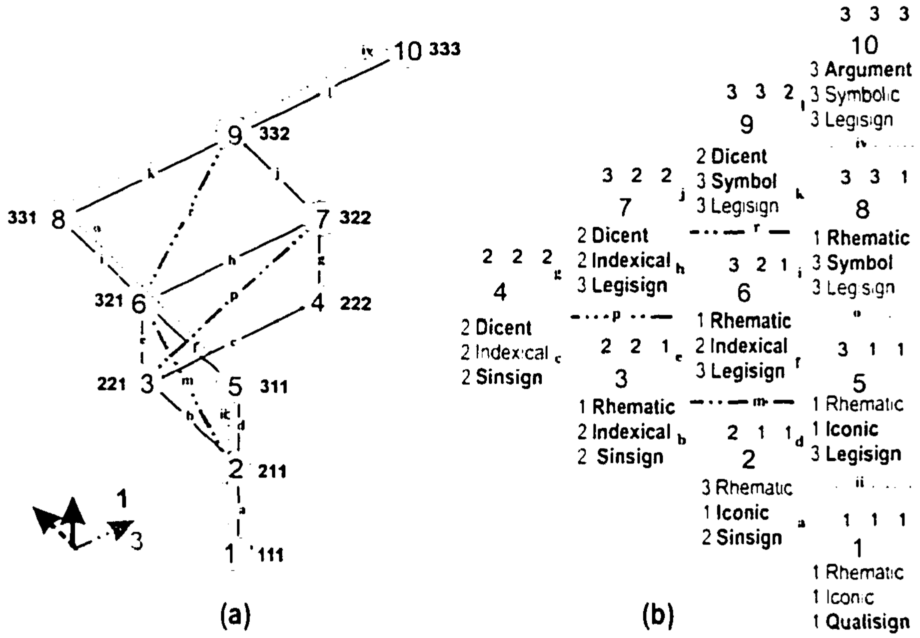
The main advantage of the particular Hasse diagram depicted in Figure 4.31 is its apparent simplicity. The simplicity of form masks a complexity of content. Indeed the model encompasses both a three-dimensional representation of the associated poset and the Hasse diagram. This offers considerable advantages over the solutions presented by other authors. Indeed, several diagrams found in the literature can be derived as special cases of the one in Figure 4.31, as I address in the sequel.

4.4.3 Derivation of diagrams of the ten categories

In this section I drew some parallels between the solution proposed here and various other diagrams some of which have been presented earlier in this thesis and some of which are new to this section. sections I understand that it is not because several of these diagrams are special cases of the solution I propose here that they are worse or better.

The first diagram I have chosen to compare is Peirce's "triangular table" or staked boxes. I have redrawn it in another orientation, as depicted in Figure 4.32, and labeled the block interfaces according to a graph developed by (Merrell, 1996, p 136), which is analyzed later in this section.

In Figure 4.32 it is possible to see the elegance of Peirce's solution. The lighter solid boundaries in Peirce's triangular table are those in which the categories differ in only one respect. Most of them correspond to the edges in the spatial Hasse diagram. There are three between nodes (1,5), (5,8) and (8,10), depicted with dotted lines.



(a) (b)

Figure 1.32: **Peirce's triangular diagram and the spatial Hasse diagrams**

which also differ in one respect, but which differ in a distance of two, going from firstness to thirdness in a single respect. The remaining links are exactly the heavier lines in the interfaces (2,6), (3,7) and (6,9) which correspond exactly to diagonals coplanar with only two axes. In other words, they differ in two respects.

In Figures 1.9and 1.10 I have illustrated how Peirce's triangular table was related to a collapsed arborescent diagram. It is also possible to derive some of the diagrams presented in the literature either through projections or a series of transformations, including folds, rotations, and translations of the spatial Hasse diagram onto a plane or surface. A similar form of transformation includes the unfolding of the solid onto a plane, followed by rotations and translations to orient the diagram in relation to an existing one. This process of unfolding the solid preserves the distances represented on the links, maintaining the relative distance of two connected nodes. Other distances are not necessarily preserved.

For example, Peirce's triangular table may be obtained through the unfolding of

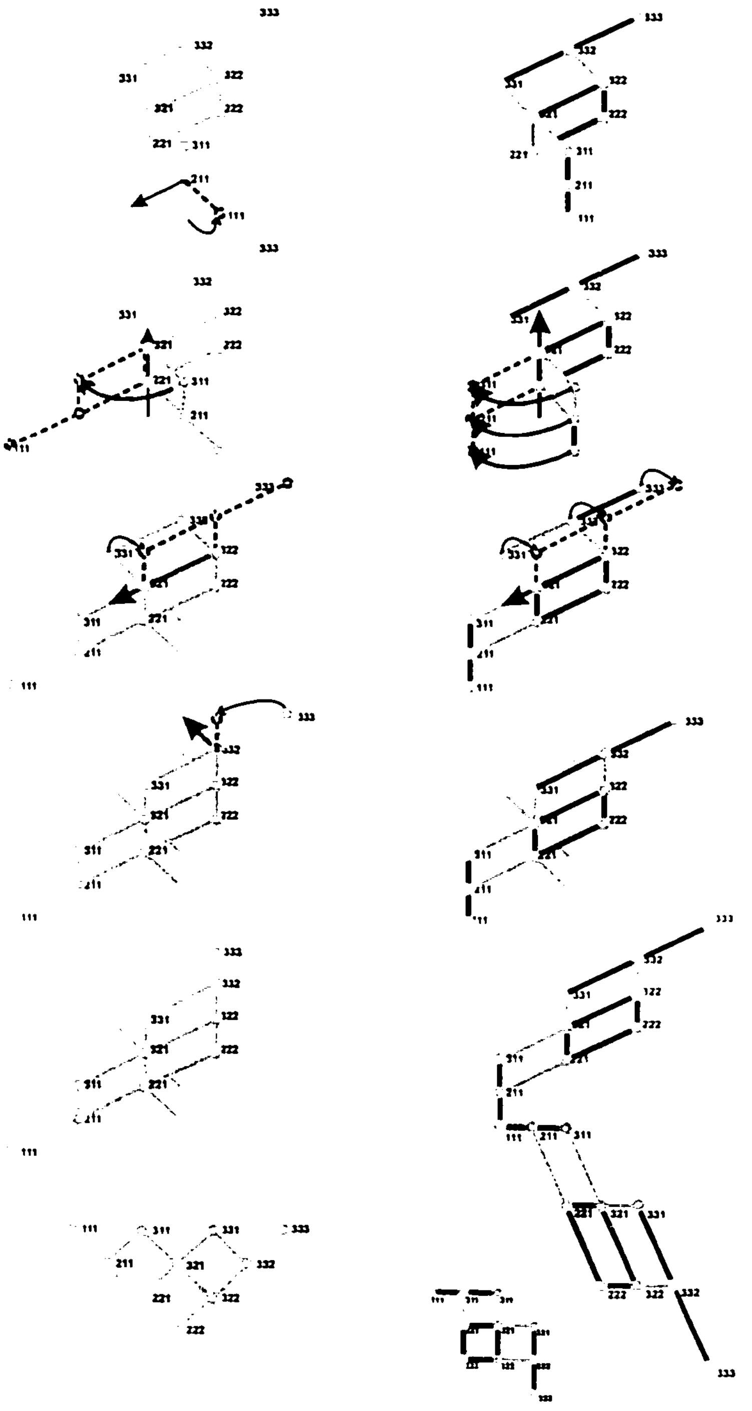


Figure 4.33: **Unfolding Peirce's and Balat's tables**

the spatial Hasse diagram. The process is illustrated in the sequence depicted in the left column of Figure 4.33. In the right of column Figure 4.33 the similar process parallels the relationship with Balat (1990)'s two-dimensional tables depicted before in Figure 4.14.

A parallel with Marty's lattices is straightforward, which was illustrated in Figure 4.30(a). It is important to stress that Marty had already characterized the categories as having a partial order and forming a lattice in the mathematical sense (Marty, 1982, p 178-9). The notations Marty used vary greatly across his writings, and in my personal opinion are not easily grasped without some effort. However, they are in accordance with the mathematical formalization he intended.

In Figure 4.34, I have compared Marty's lattice with the spatially organized Hasse diagram proposed in this thesis. The links in Figure 4.34(a) have been reproduced as in Marty's lattice. The dashed arrows are only between the nodes linking elements containing the third and the second cenopythagorean categories.

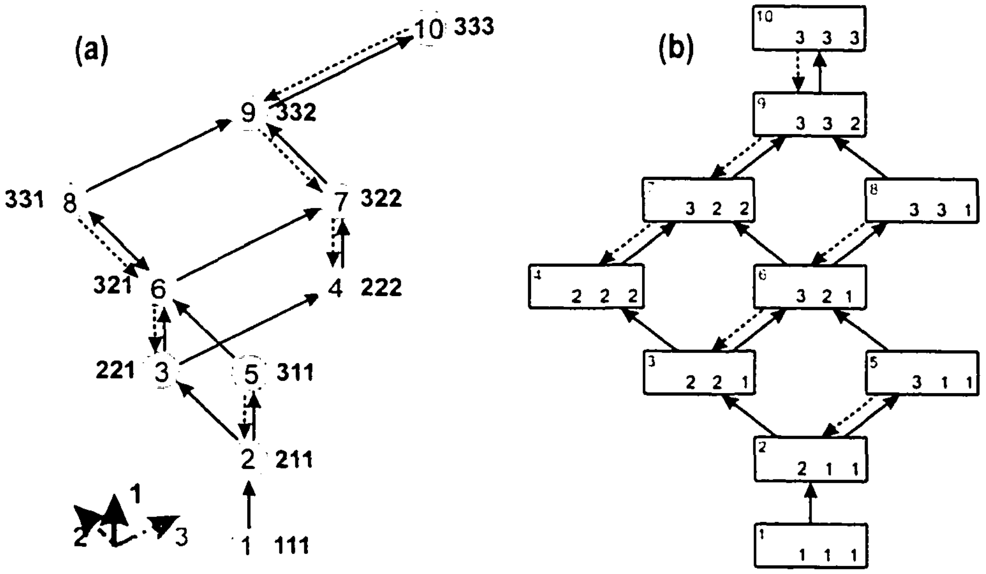


Figure 4.34: **A comparison with Robert Marty's lattice**

The semantics and pragmatics associated with these links are open to research and deal with the semiotics processes. Related concepts in Peirce's work involve degeneracy within the categories, and processes of induction, deduction, and abduction, which are all deeply entwined with processes of abstraction and prescision.

These are topics of interest in Peircean scholarship some of which have been explored by Merrell (1996) in several of his writings. I have already shown one of his diagrams in Figure 4.29 depicting the relations of presupposition among the categories. In Figures 4.35 and 4.36 I have redrawn two of Merrel's graphs denoting relations between the ten categories according to the conventions fostered here.

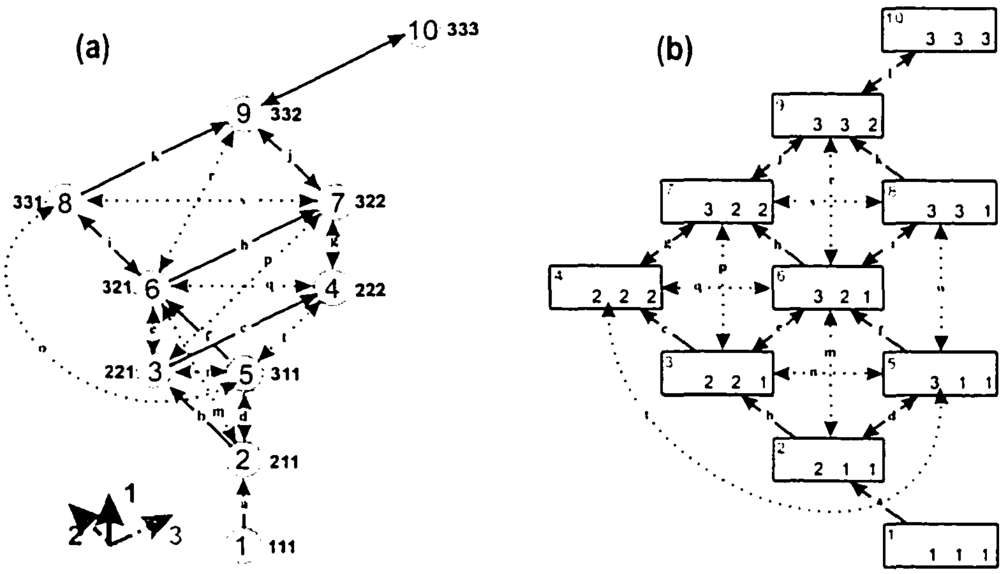


Figure 4.35: **A comparison with one of Merrel's "lattice like" graphs**. (Merrell, 1996, p 138, redrawn)

There are multiple ways to draw a graph. Merrel has redrawn the graph in Figure 4.36(b) in a form similar to the one represented in Figure 4.35.[11]

Figure 4.36(b) is organized horizontally according to the second trichotomy, from left to right, and vertically according to the usual linear order in which the categories are labeled. Merrel referred to the labeled links in his graph as taking "signs across boundaries as the signs become transmuted into something more than or less than.

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[11] I remark that I have modified Merrel's graphs only to facilitate the comparison with the spatial Hasse diagram and Peirce's triangular stacked boxes.

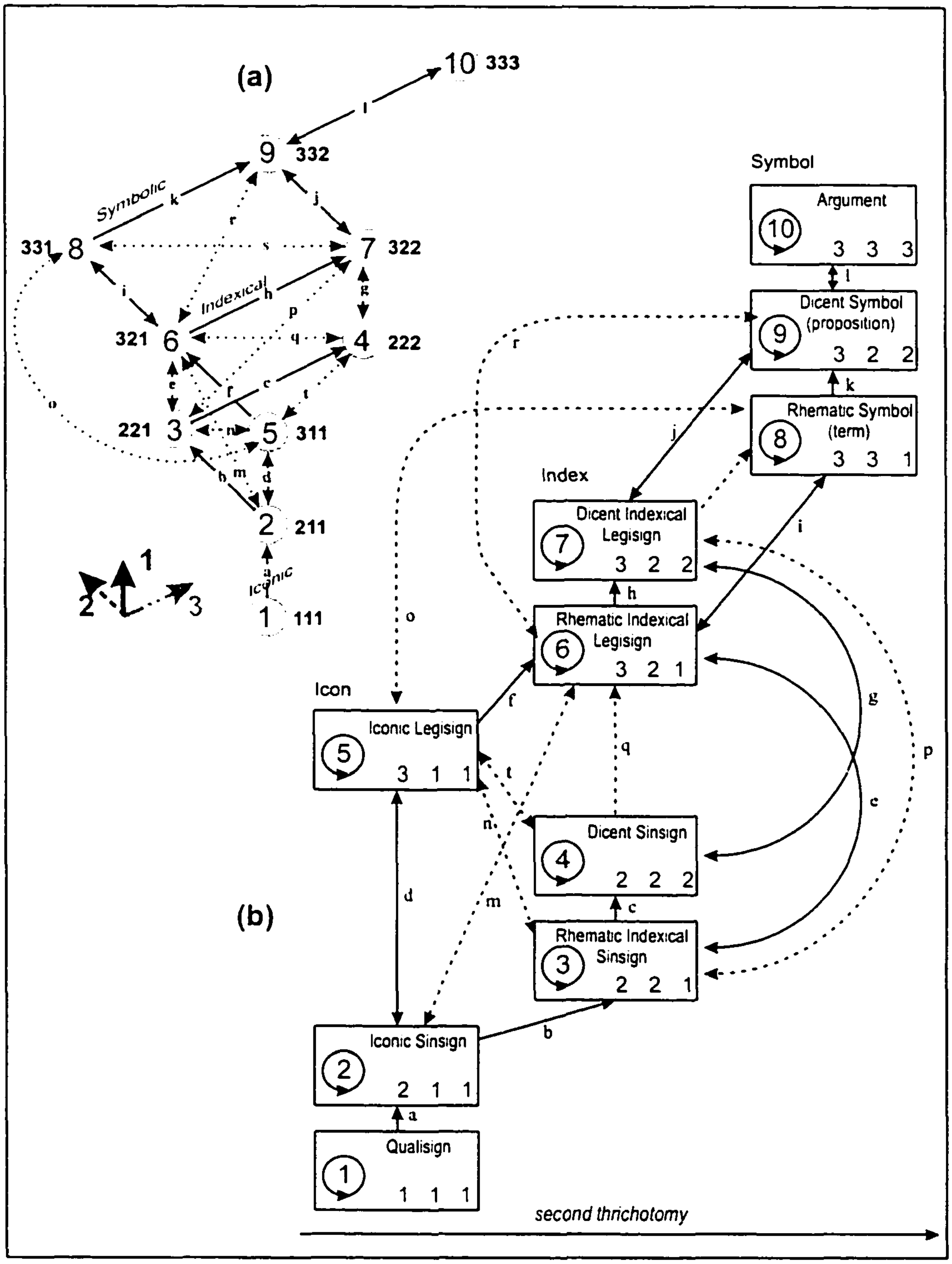

Figure 1.36: **A comparison with one of Merrel's graphs:** based on (Merrell, 1996, p 136, redrawn)

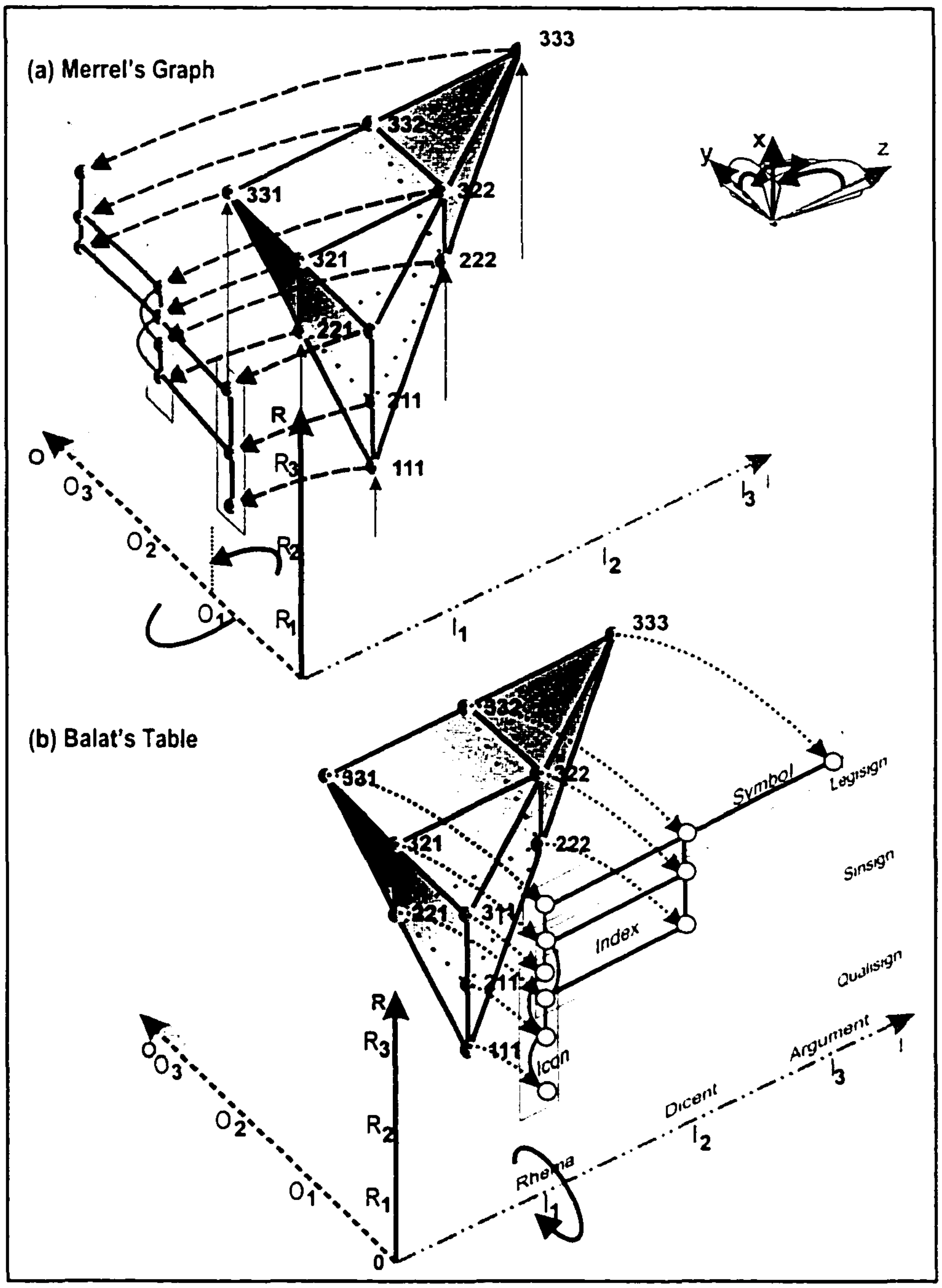

Figure 4.37: **Derivation of Diagrams through projection by rotation:** (a) derivation of Merrel's graph; (b) derivation of Balat's table.

but always distinct from what they were." (Merrell, 1996, p 139). I have not explored Merrel's explanations given to these links.

Projections which can be based on translations or rotations usually preserve some of the relationships of order present in the three-dimensional space. Figure 4.37 illustrates how it is possible to obtain a graph with the same spatial organization of Merrel's graph depicted in Figure 4.35 and of Balat's table depicted in Figure 4.33.

The projections in Figures 4.37(a) and (b) preserve the second and third trichotomy spatial relations, respectively. Merrel's graph depicted in Figure 4.37(a) is linearly organized with the second trichotomy (icon, index, and symbol). The projection plane (x,y) illustrated in Figure 4.37 has a very similar graphical disposition, including the need to use curved links to go around nodes.[12]

Similarly, a projection around the z-axis (I) preserves the spatial relations of the third trichotomy (Rhema, Dicent, and Argument). Balat's table used the first and the third trichotomy to organize his two-dimensional diagram redrawn in Figure 4.37(b). The rotation has been done around the I-axis, therefore all the classes that include at most rhemas end up aligned.

4.4.4 Categories derived form different enumerations

I started this chapter exploring the different conceptions of sign relation, and the multiple sequences ascribed to its components. These various conceptions indicate a lack of agreement on fundamental frameworks that model semiotic processes. I now explore, with the aid of a spatial Hasse diagram of the ten categories poset, some implications of a different order for the components of a ternary sign relation.[13]

Peirce developed yet another diagram to illustrate his arguments about categories of signs. In a letter to Lady Welby about decadic signs he enclosed the triangular

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[12] A direct projection would draw some links or nodes on top of others, depending upon which vector the rotation is done around.I have chosen only the examples in which rotations are developed around the x- and z-axes, which represent the representamen (R) and the interpretant (I), respectively.

[13] In the last section of this chapter, I develop a similar analysis for Peirce's decadic sign relations.

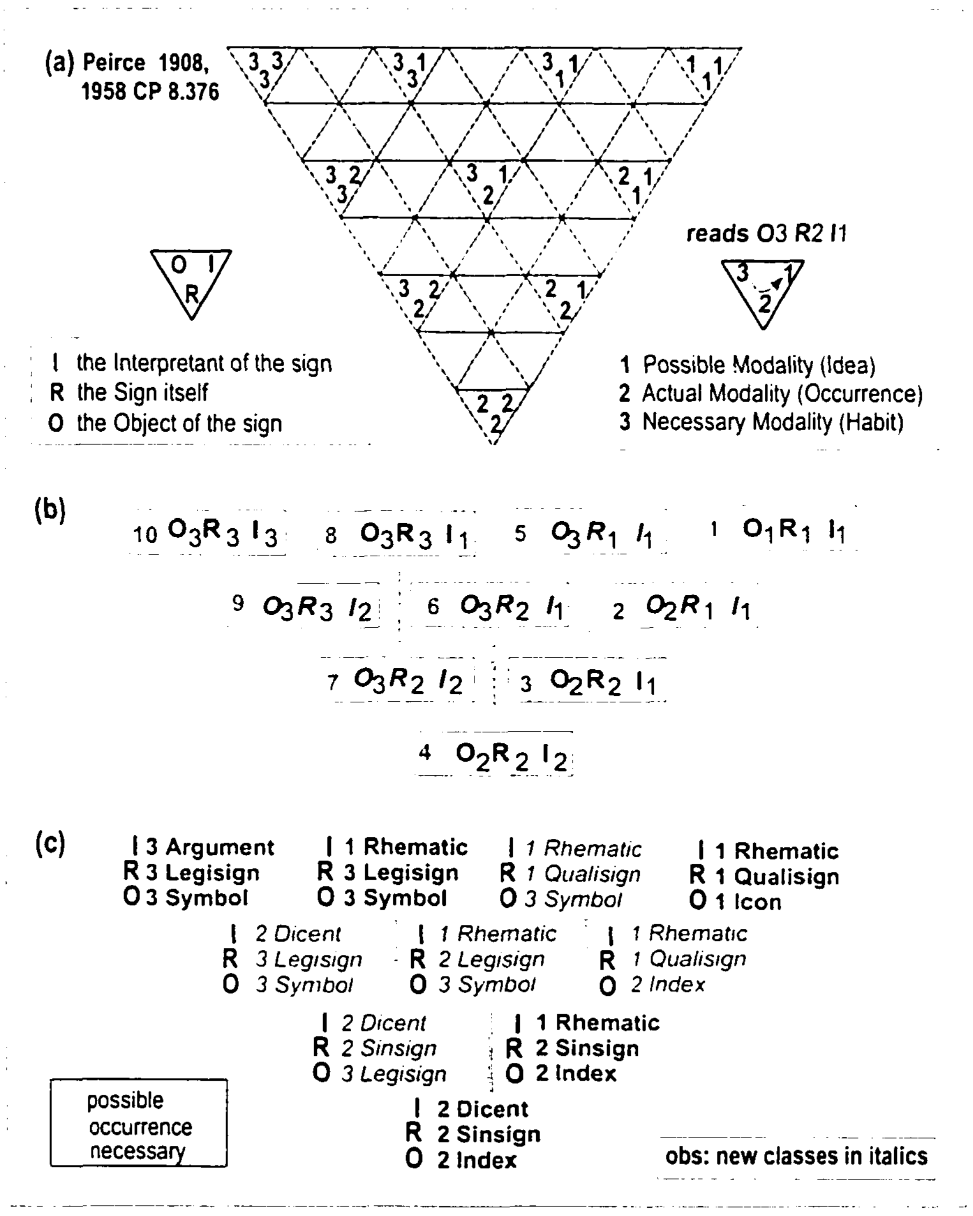

Figure 1.38: **Peirce's other triangular diagram:**(a) Peirce developed a second triangular diagram. He used triangles instead of boxes. (b) If one follows the explanation found in Peirce (see 1958, 8.376) and quoted in the text, a different set of categories is derived. (c) The new classes are shown in italics.

diagram depicted in Figure 4.38(a). The particular illustration in Figure 4.38(a) is interesting because Peirce himself described the triadic sign relation in a different order. However, the order between possibility, occurrence, and necessitant, continued in accordance with the cenopythagorean categories. Peirce described the vertices of each triangle (left, bottom, right) as Objects, Signs,[14] and interpretant, respectively:

> "[In Figure 4.38 the] number above the left describes the Object of the Sign. That above the right describes its Interpretant. That below describes the Sign itself. 1 signifies the Possible Modality, that of an idea. 2 signifies the Actual Modality, that of an Occurrence. 3 signifies the Necessary Modality, that of a Habit." (See Peirce, 1958, 8.376)

The combination of numerical indexes is the same, both in this diagram and in the "triangular table". The graphical orientation is different. In semiotics I have found both illustrating the ten categories of ternary signs. However, if the order in Peirce's quote were accepted as correct, some of the ten derived categories would not coincide with the ones Peirce studied throughout his career. Figures 4.38(b) and (c) illustrate the possible categories that would be derived if the sequence representamen, object, and interpretant were changed to object, representamen, and interpretant.

There is a myriad of semiotic analysis based on semiotic triangles. Across them, many tend to stream the sign relation linearly into two dyads, tending to the relation $O \rightarrow S \rightarrow I$. This tendency is in accordance with the linear view of the world so disseminated in our culture, as I have commented throughout this thesis. Even the most radical proponents of triadic semiotics often fall into this trap, and end up doing monadic semiotics in which everything *is* a sign, where the absolute reigns and the relative, the mediated, the meaningful, and the ethical, among others are not considered.

The assumption of a different order for the sign relations, if accepted as right and not as Peirce's mislabel, would have consequences across Peirce's entire systematic philosophy. For example, mathematics would have to presuppose philosophy.

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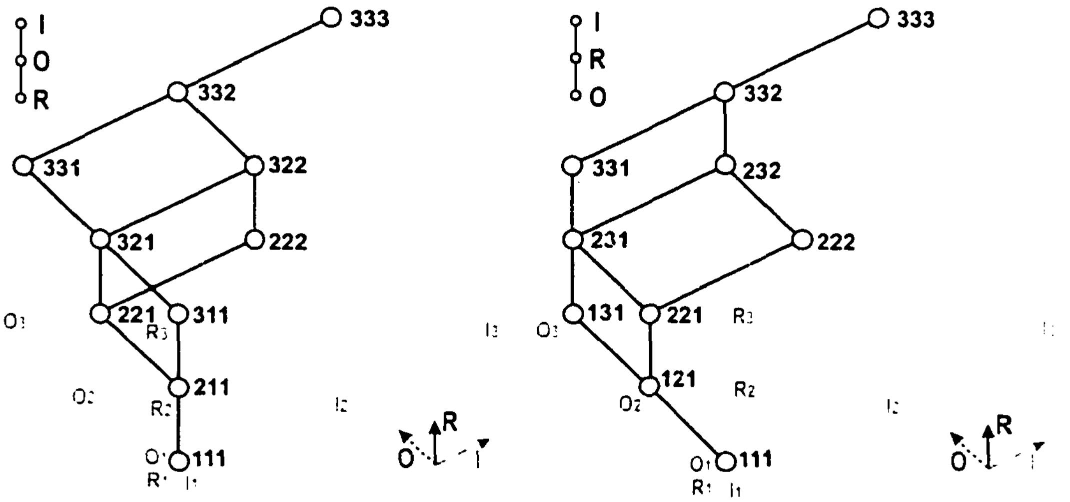
[14] I have been using the term Representamen instead of the term Sign.

phenomenology would have to presuppose the normative sciences, and so on. See Figure 1. As I already remarked, a discussion of the feasibility of such a possibility is outside the scope of this chapter. Nevertheless, the semantical aspects of semiotics presuppose the syntactical ones in Peirce's philosophical scaffold, which implies that care should be taken to establish solid foundations.



(a) Representamen, Object, Interpretant (b) Object, Representamen, Interpretant

Figure 1.39: **Derived lattices:** (a) $R \rightarrow O \rightarrow I$ (b) $O \rightarrow R \rightarrow I$. Different categories are derived from different orders among the elements of a sign subdivision.

I have depicted in Figure 1.39 the differences in the spatial Hasse diagrams of the two sets of derived categories considering different sequences between representamen and object in the triadic sign relation. Figure 1.39(a) depicts Peirce's ten categories derived from a sign relation grounded in the order ($R \rightarrow O \rightarrow I$). Figures 1.39(b) and (c) depict Peirce's ten categories derived from a sign relation ground on the order ($O \rightarrow R \rightarrow I$). A different order between R and O implies the same geometrical cut of the parallelepiped containing the twenty-seven possibilities. However, the valid region is different, as illustrated in Figure 1.39.

I have assumed the partial order ($R \rightarrow O \rightarrow I$), because it is consistent with the organization of Peirce's Systematic Philosophy (Mathematics → Normative Sciences → Practical Sciences), with the organization of semiotics itself (Speculative Grammar

→ Critic → Methodeutic), with the organization with the cenopythagorean categories (Firstness → Secondness → and Thirdness), and with the organization of the decadic categories as studied by Peirce. It is also the same order used by Peirce in the passage published in (Peirce, 1958, 8.344) in which Peirce correlated the first two trichotomies derived from a decadic sign relation and illustrated in Figures 4.11 (c) and (d). Additionally, this order is used as the narrative structure of the texts in which he discussed the categories.

In the next section, I explore Peirce's multiple sign relations. The approach will be very similar to the one already presented, though the trees, tables, and Hasse diagrams have a larger number of elements and possible combinations. The same tendency to strictly order sign processes is clear within the different opinions found across the literature.

4.5 Decadic Sign Relations

In this section I explore Peirce's higher order sign relations and the derivation of the corresponding categories. As in the preceding sections, I stay mostly limited to the syntactical aspects of these relations, but I indicate semantically and pragmatically oriented issues when appropriate. This topic has been mostly restricted to Peircean scholarship.

I include this section to reinforce the understanding of signs as processes. Signs go well beyond classificatory schemata. The multiple opinions about the organization of sign relations of cardinality higher than three, and the tendency to linearize what is partially ordered, only come to reinforce the urgent need of a reflection within semiotics about its historical biases. It also reinforces the advantages of a two-way cross-pollination between semiotics and informatics. While ternary signs have relatively simple structures, decadic signs have more complex structures. Decadic sign relations have structures as complex as the categories of ternary signs.

Peirce further refined triadic sign relations into hexadic and decadic sign relations.[15] A larger number of elements in a sign relation implies both a larger number of trichotomies and a larger number of derived classes.

In the case of the ten categories derived from the ternary sign relation, Peirce differentiated each element of the sign relation with the cenopythagorean categories, generating three trichotomies. Their correlation resulted in ten valid combinations (categories) among twenty-seven possible ones, as illustrated in the preceding sections.

According to Peirce, twenty-eight among 729 categories can be derived from the hexadic sign relation, and sixty-six among 59049 categories can be derived from the decadic sign relations (Peirce, 1958, 8.343). These numbers are linked to the possible arrangements between six and ten elements, and by the constraints imposed by strictly ordered sign relations. This point may be controversial and demands further research involving the semantics and pragmatics of these sign relations. Indeed, this refinement was a very open problem even for Peirce. Peirce was experimenting with the terminology, and did not have "clear apprehension" of the derived trichotomies (Peirce, 1958, 8.341).[16] [17]

The processes and the resources used to visualize these sign relations and categories are basically the same as the ones already viewed in the preceding sections. If sign relations were not strictly ordered, as Peirce assumed, but partially ordered, there could be more categories than twenty-eight or sixty-six, respectively, because there would be multiple ways of traversing the corresponding lattices. Spatial Hasse diagrams are appropriate to describe additional classes once the whole set of possible categories scaffold the valid ones.

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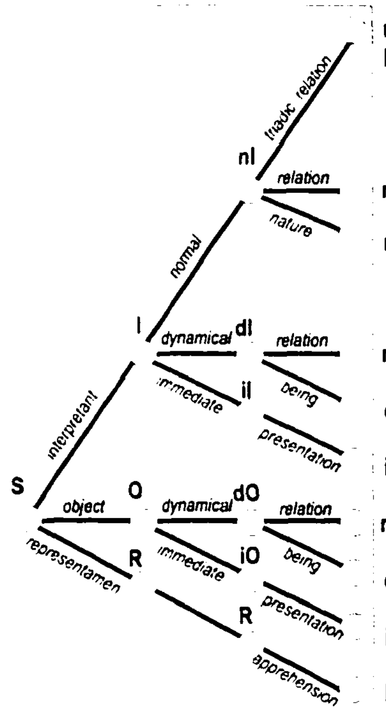
[15] See (Peirce, 1958, 8.343) and (Peirce and Welby-Gregory, 1977, p 66–86)

[16] Peirce listed the subdivision in different orders in different passages ((Peirce and Welby-Gregory, 1977, p 84, 1908 December 14) and (see Peirce, 1958, 8.376); or (Peirce, 1958, 8.344) and (Peirce, 1931-1935, 2.236)), and explicitly left the "systematical division of signs [...] for future explorers (Peirce, 1958, 8.341).

[17] Peirce wrote: "I do not say these divisions are enough. But since every one of them turns out to be a trichotomy, it follows that in order to decide what classes of signs result from them, I have 3^{10}, or 59049, difficult questions to carefully consider; and therefore I will not undertake to carry my systematical divisions of signs any further, but will leave that for future explorers. (Peirce, 1958, 8.343).

At the end of 1908, Peirce explored higher order sign relations, the associated trichotomies, and the corresponding derived categories in two letters to Lady Welby (Peirce and Welby-Gregory, 1977, pp 66-86). To scaffold the refinement, Peirce recognized three universes, which were "distinguished by three Modalities of Being": the universe of ideas or **Possibles**; the universe of **Existants** concerning objects, 1st, and Facts, 2nd; and the universe of **Necessitants** (Peirce and Welby-Gregory, 1977, pp 81-3, 1908 December 11). He correlated[18] the elements of the ternary sign relation (Representamen, Object, and Interpretant) with the modalities of being, but instead of deriving categories, he refined the ternary sign relation, increasing its cardinality. Peirce relabelled them immediate, dynamic, and normal, in reference to possible, existant, and necessitant, respectively.

Peirce's 10 chief divisions of signs are determined according to the:



rel R-dO-nI	**Triadic Relation of the Sign to its Dynamical Object and its Normal Interpretant**
rel R-nI	**Relation of the Sign to the Normal Interpretant**
nI	**Nature of the Normal Interpretant**
rel R-dI	**Relation of the Sign to the Dynamical Interpretant**
dI	**Mode of Being of the Dynamical Interpretant**
iI	**Mode of Presentation of the Immediate Interpretant**
rel R-dO	**Relation of the Sign to its Dynamical Object**
dO	**Mode of Being of the Dynamical Object**
iO	**Mode of Presentation of the Immediate Object**
R	**Mode of Apprehension of the Sign Itself**

Figure 4.10: **Peirce's decadic sign relation** (Peirce, 1958, 8.342-345)

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[18] This correlation is equivalent to the one Peirce used to derive the ten categories, in which sign components were correlated with the cenopythagorean categories.

Peirce then analysed the sign itself and its possible modalities, and distinguished two Objects of a Sign (R), which he labelled Immediate Object (O_i) and Dynamic Object (O_d) and analyze their modalities. The Immediate Object is the object within the sign. The Dynamic (or dynamoid) Object is the object outside the sign. The rationale is the same as that used to derive the ten categories from the triadic sign relation. A first contains only itself, but a second contains first and seconds, and so on. The use of a tree is illustrative to reinforce this argument. I depict on Figure 4.10 a graphic reading of the ten subdivisions of decadic sign relations, as explained below. The edges of the tree in Figure 4.10 have been labelled according to the modes Peirce used to further refine the ternary relation.[19]

Peirce textually listed the other components of the decadic sign relation. He explicitly quantified the possibility of having the six plus four trichotomies, and 3^6 or 3^{6+4} different forms of arranging them:

> It is evident that a possible can determine nothing but a **Possible**, it is equally so evident that a **Necessitant** can be determined by nothing but a Necessitant. Hence it follows from the Definition of a Sign that since the Dynamoid [Dynamic] Object determines the Immediate Object,
> Which determines the Sign itself,
> which determines the Destinate [Final I_n] Interpretant,
> which determines the Effective [DynamicI_d] Interpretant,
> which determines the Explicit [Immediate I_i] Interpretant
> the six trichotomies, instead of determining 729 [3^6] classes of signs, as they would if they were independent, only yieled 28 classes; and if, as I strongly opine (not to say almost prove) there are four other trichotomies of signs of the same order of importance, instead of making 59049 [3^{10}] classes, these would only come to 66. (Peirce and Welby-Gregory, 1977, p 84, 1908 December 14)

The order in which Peirce listed these elements has been a source of controversy in the specialized literature, because it does not follow the usual rationale he maintained

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[19] Jean Fisette used an arborescent structure to describe Peirce hexadic (Fisette, 1990, p 48) and decadic (Fisette, 1990, p 60) sign relations. Muller described the derivation of sign relations trough something similar to a tree (Müller, 1994, p 138 and 143).

throughout his life. This is an issue that needs to be further researched in conjunction with semioticians. It involves aspects that go well beyond the structural explorations of signs. In my opinion, however, the textual order of this particular passage should not be used in contradiction of Peirce's other passages and his entire philosophy, as I detail later. In a subsequent letter to Lady Welby, Peirce explained what he meant by the immediate, the dynamical, and the final interpretant, which he called explicit, effective, and destinate, respectively, in the above quote. This terminology suggests temporal dependencies involved in the interpretive semiotic processes. Peirce was clearly experimenting with the terminology. He changed the denomination used to describe the interpretant (explicit, effective, and destinate) (Peirce and Welby-Gregory, 1977, p 84, 1908 December 14) to the same qualifiers used to describe the object, **immediate** and **dynamic**, and added a **final** one (Peirce, 1958, 8184 and 8.342-345). The following passage is illustrative:

> My Immediate Interpretant [iI] is implied in the fact that each Sign must have its peculiar Interpretability before it gets any Interpreter. My Dynamical Interpretant [dI] is that which is experienced in each act of Interpretation and is different in each from that of any other; and the Final Interpretant [nI] is the one interpretative result to which every Interpreter is destined to come if the sign is sufficiently considered. The Immediate Interpretant is an abstraction, consisting in a Possibility. The Dynamical Interpretant is a single actual event. The Final Interpretant is that toward which the actual tends." (Peirce and Welby-Gregory, 1977, p 111, 1909 March 14, capitals in the original)

Peirce explicitly listed the components of a hexadic sign relation in a draft of a letter to Lady Welby sketched between 24 and 28 December 1908. In this draft Peirce described the subdivision of the hexadic sign relation and in the sequence listed the ten "respects according to which the chief divisions of signs are determined". Peirce described the refinement of a triadic sign relation into a hexadic one in the following passage:

> I define a *Sign* [R] as anything which on the one hand is so determined by an Object [O] and on the other hand so determines an idea in a person's mind, that this latter

> determination, which I term the *Interpretant* [I] of the sign, is thereby mediately determined by that Object. A Sign therefore has a triadic relation to its Object and to its Interpretant. But it is necessary to distinguish the *Immediate Object* [iO], or the Object as the Sign represents it, from the *Dynamical Object* [dO], or really efficient but not immediately present Object. It is likewise requisite to distinguish the *Immediate Interpretant* [iI], i.e. the Interpretant represented or signified in the Sign, from the *Dynamic Interpretant* [dI], or effect it actually produced on the mind by the Sign; and both of these from the *Normal Interpretant* [nI], or effect that would be produced on the mind by the sign after sufficient development of thought. On these considerations I base a recognition of ten respects in which Signs may be divided. (Peirce, 1958, 8.343)

While the above quote refined the elements of the ternary sign relation (representamen, object, interpretant), they were still unrelated. The additional *relations* among the elements clothe them into the decadic sign relation, giving structure to it. Indeed, Peirce continued his refinement with a list of the ten chief divisions of decadic sign relations. As he wrote, "the ten respects according to which the chief divisions of signs are determined are as follows":

> 1st, According to the Mode of Apprehension of the Sign itself, [R]
> 2nd, According to the Mode of Presentation of the Immediate Object, [iO]
> 3rd, According to the Mode of Being of the Dynamical Object, [dO]
> 4th, According to the Relation of the Sign to its Dynamical Object, [(R,dO)]
> 5th, According to the Mode of Presentation of the Immediate Interpretant, [iI]
> 6th, According to the Mode of Being of the Dynamical Interpretant, [dI]
> 7th, According to the Relation of the Sign to the Dynamical Interpretant, [(R,dI)]
> 8th, According to the Nature of the Normal Interpretant, [nI]
> 9th, According to the Relation of the Sign to the Normal Interpretant, [(R,nI))]
> 10th, According to the Triadic Relation of the Sign to its Dynamical Object and to its Normal Interpretant. [(R,d0,nI)] (Peirce, 1958, 8.344)

The order in the above quote is consistent with the way Peirce numbered the ten categories of the ternary sign relations. Decadic signs can be easily understood with the aid of trees and Hasse diagrams. Figure 4.11 illustrates the refinement of ternary sign relations into decadic one, passing through an hexadic subdivision. The prescision principle is also observed in Peirce's refinement, as the following four items indicate:

(a) In reference to the original triadic sign relation, the representamen (R) remained undivided because it was regarded as a first, and as such it could not be subdivided or differentiated.

(b) The object (O), though being usually associated with secondness in its genuine form, could be distinguished in two forms: the immediate object (iO, the suggested object in the sign), and dynamic object (dO, the actual object in the sign relation).

(c) The interpretant, being usually associated with thirdness in its genuine form, could be refined as immediate (iI), dynamical (dI), and final (nI, or normal).

(d) The cenopythagorean categories of firstness, secondness, and thirdness correspond to monadic, dyadic, and triadic relations. If there is an object inside the sign and another outside it, and if there are interpretants already in the sign, in the sign event, and towards which the sign tends, the relations among these elements should scaffold the sign relation, otherwise it would be disconnected. As I mentioned before, dyadic and ternary relations gave structure to the decadic sign relation.

On the left of Figure 4.11(a) is the ternary sign relation depicted as a tree, and its corresponding spatial Hasse diagram on the right. In Figure 4.11(b) I present the first refinement into an hexadic relation: a tree with six leaves on the left and a two dimensional Hasse diagram on the right. The full decadic sign relation is on the left of Figure 4.11(c) , with the corresponding lattice on the right. I have assumed that the partial order of the cenopythagorean categories also holds in the two refinements of the sign relation. I developed the spatial Hasse diagrams in Figure 4.11 assuming syntactic consistency with Peirce's work as a whole.

As I have already remarked, the systematic organization of Peirce's sign subdivision is present in the way he described the modes of being of decadic sign subdivision. In Figure 4.10 I have labelled the tree's arcs according to Peirce's own explanation (Peirce, 1958, 8.344). I should stress that I have not further explored either the semantics or the pragmatics Peirce gave to these refinements. However, the process of derivation of categories, as he described, seems to be in accordance with this pattern, and with some other passages, as I explore in the next section.

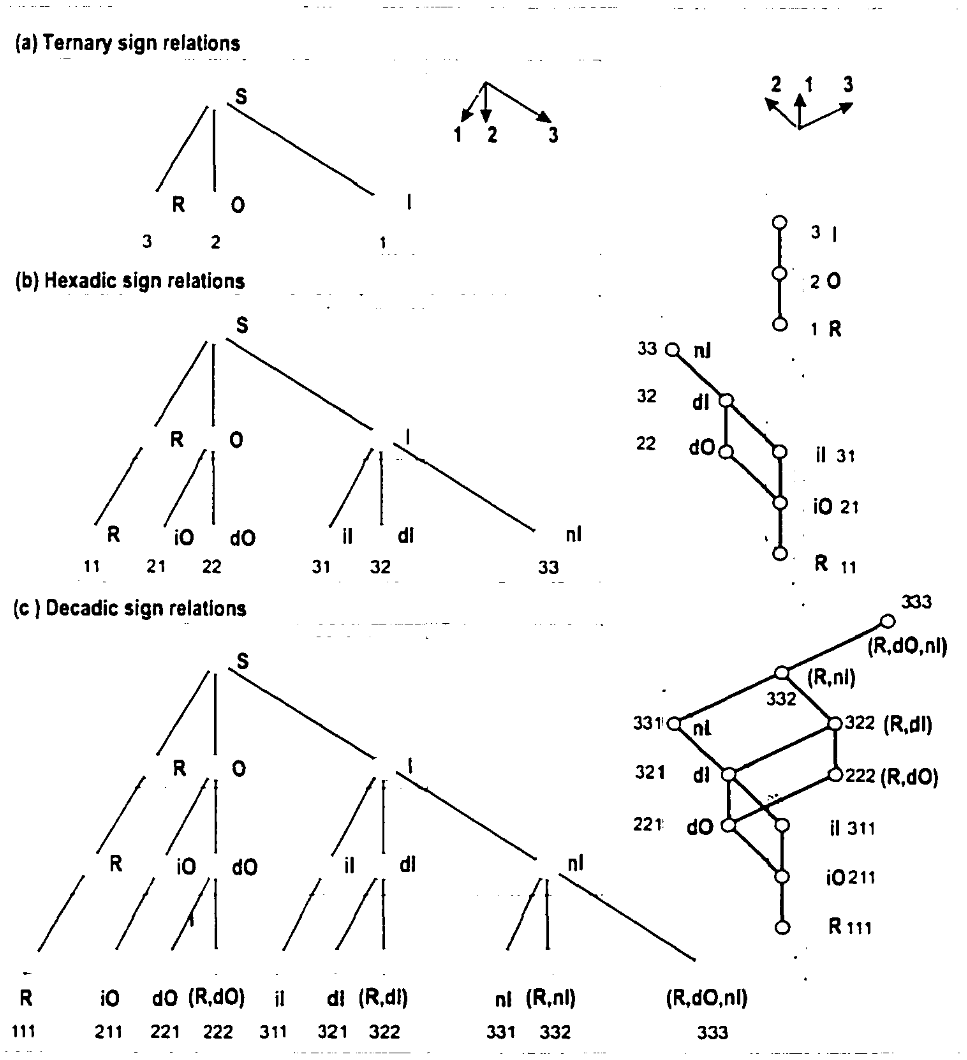
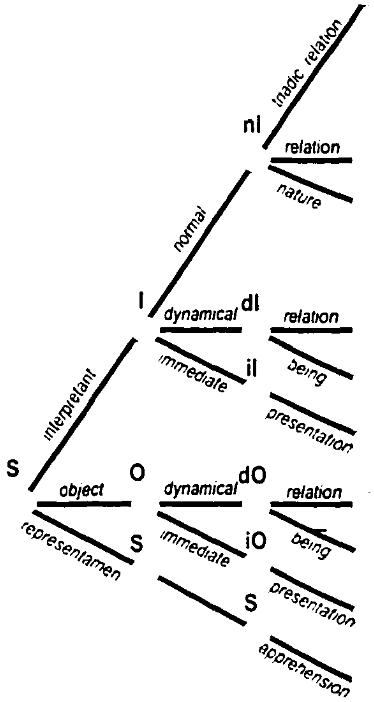


Figure 4.11: **Refinements of ternary sign relations into decadic relation**

4.5.1 Categories of Decadic Sign Relations

A small number of authors have discussed the derivation of categories from hexadic and decadic sign relations. Weiss and Burks (1945) have listed a decimally trichotomous division of signs and have presented a table with sixty-six categories. Sanders criticized Weiss and Burks for listing the ten trichotomies derived from a decadic sign relation without paying attention to their dependencies (Sanders, 1970, p 11). I repeat, in my understanding, the order in which the ten subdivision are listed is not important if their relation of order is observed in the derivation of the classes.[50] Sanders main contribution was to point out the relation between the subdivision of the sign and the derived classes. He did not explore further the affinities between the subdivisions and the associated order among them.



rel S-dO-nI	Instinctive	Experiential	Formal
rel S-nI	Rheme	Dicent	Argument
nI	Gratific	Practical	Pragmatic
rel S-dI	Suggestive	Imperative	Indicative
dI	Sympathetic	Percussive	Usual
iI	Hypothetical	Categorical	Relative
rel S-dO	Icon	Index	Symbol
dO	Abstractive	Concretive	Collective
iO	Descriptive	Designative	Copulant
S	Potisign	Actisign	Famisign

Figure 1.42: **Peirce's ten trichotomies of a decadic sign relation** See (Peirce, 1958, 8.342-345)

In a table that correlates decadic sign relations with the cenopythagorean categories each element can assume three values, which results in ten trichotomies. Peirce

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[50] That is not the case in Weiss and Burks (1945), because they label the columns of the derived classes table according to the labels given to the ten subdivisions (from A to J).

named and gave examples of the elements of these trichotomies, as depicted in Figure 4.42.

As with ternary sign relations, a table that would list all the possible arrangements of a decadic sign would have 3^{10} or 59059 entries. The cenopythagorean categories are strictly ordered. The subdivision of decadic signs, if understood as above, are partially ordered sets that are lattices. The order is partial because it does not need to be linear or strict. This does not imply that it is impossible to enumerate the elements of the partially ordered set (or poset). In fact, every finite poset admits of a consistent enumeration (Preparata and Yeh, 1974, p 185). This means that the elements of a poset can be enumerated in different sequences. For example, in a decadic sign relation it is possible to list after the dO either (R, dO) or iI. Both are valid possibilities.

When Peirce calculated that sixty-six categories are derived from decadic signs, he assumed only one enumeration of the sign relation's components. Indeed, Peirce ordered the decadic sign relation in a similar manner to the numbers he gave to the ten categories of ternary sign relations. The table in Figure 4.43 lists the 3^{10} elements that would correspond to the categories of decadic signs derived from this enumeration. This table would have more lines if more than one order were considered simultaneously.

It is possible, for example to invert two or more column labels in Figure 4.43, without changing the cells. A small remark is important. Across the table, it is possible to identify the same patterns of numbers found in categories derived from monadic, ternary, and hexadic sign relations, as illustrated. These patterns do not represent the respective categories of these sign relations. Indeed, it is possible to find the same patterns in different regions of the table. In Figure 4.44 I superimpose the decadic sign derivation tree with a different visual formalism. The enclosing rectangles are parent nodes in a tree representing the decadic sign relation, the broadest being the root node, which is the triadic sign relation.

Walther (1979, p 97) used the same order as Peirce to list the ten trichotomies, as illustrated in Figure 4.45. She did not refer to this diagram as containing relations

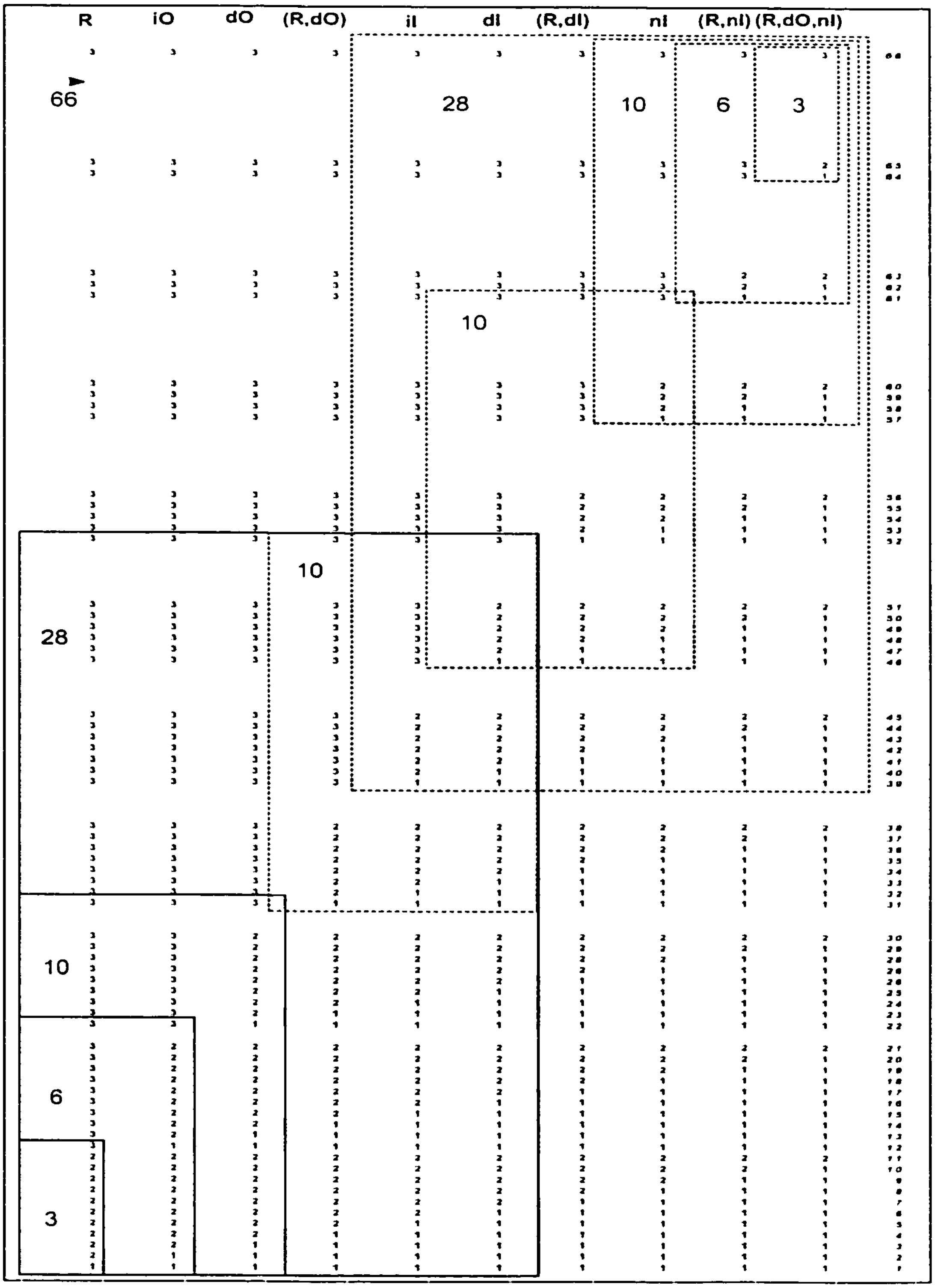

Figure 4.43: **Table with the sixty-six assumed valid arrangements**

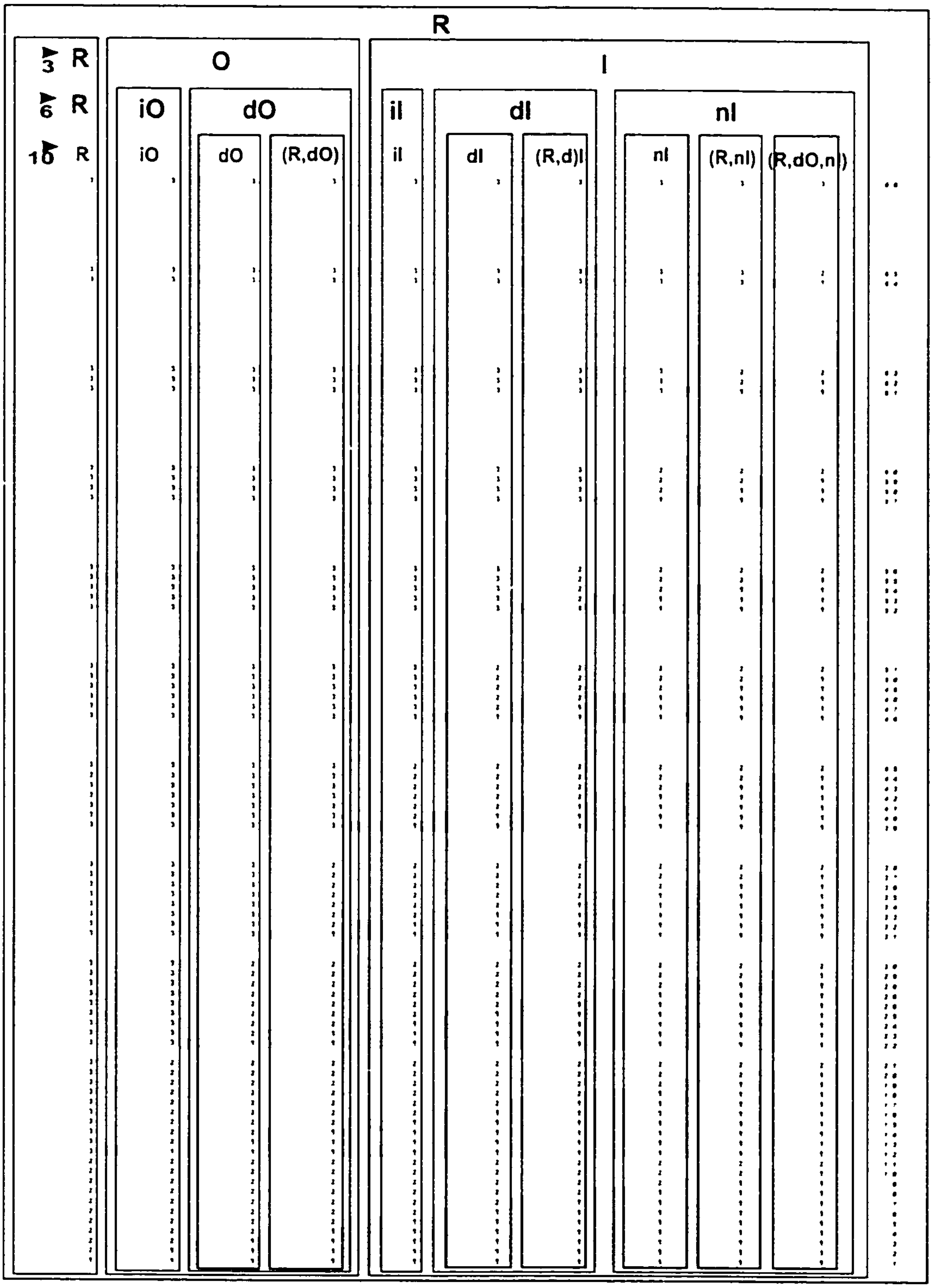

Figure 1.44: **Derivation tree and derived categories**

of inclusion, but its disposition may wrongly suggest that.[51]

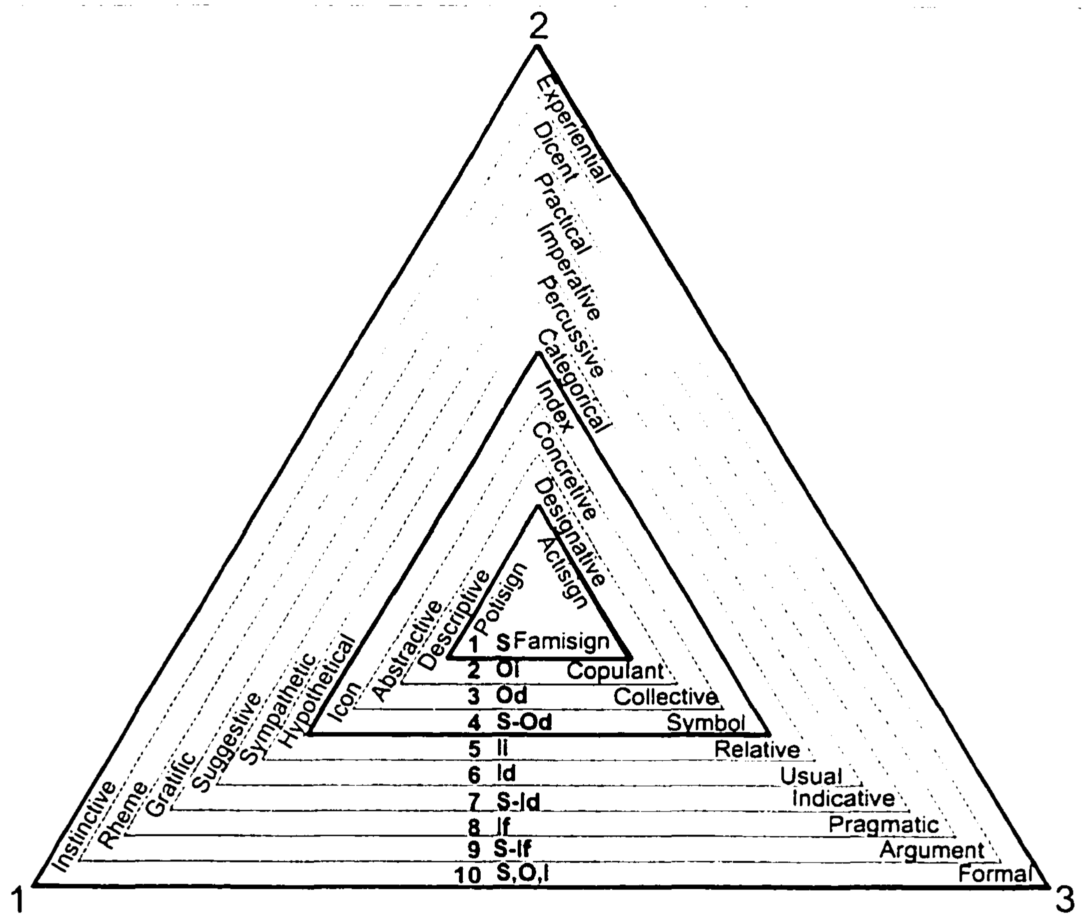

Figure 4.15: **Walther's illustration of Peirce's 10 trichotomies of decadic sign relations** (Walther, 1979, p 97, redrawn and complemented)

The acceptance of a partial order would imply that there are possibly more than sixty-six categories of decadic signs. This is a question that needs to be addressed by semioticians, to whom the conditions of truth of these categories and their generality is important. For example, in an hypothetical enumeration of a decadic sign relation, an immediate Interpretant (iI, that is the interpretant within the sign) would presuppose the dynamoid object (dO, that is the object outside the sign), and the relations

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[51] If one accepts that decadic subdivisions are lattices, a diagram similar to the one developed by Merrel and redrawn in Figure 4.29, would be a better alternative than Walther's diagram. My preference, however, is the spatial Hasse diagram.

between the representamen and the dynamoid Object (R. dO). If it presupposes, it includes, and this eliminates the possibility of learning because everything that is outside is already inside. If the covert interpretant (iI) already contains the overt object (dO), it is equates the final interpretant in its relation with them (R.dO.nI). But, it should not. It is exactly the empirical difference of the interaction with overt objects that interpreters reflect upon in order to change or not, accordingly.

However, the solution of more basic problems is necessary. One problem is similar to the different enumerations for the triadic sign relation found in the Informatics literature that have been recently exploring semiotics to guide design. See Figure 1.4 for some examples. There is no apparent agreement on the solution, other than the fact that most have been searching for a single enumeration. Moreover, Peirce scholars have been listing the components of decadic sign relations in sequences that are not in agreement even with the partial order of the corresponding sign relation, as analyze in the sequel.

The derivation of the categories of hexadic and decadic sign relations is a subject that only a few have ventured into. Peirce scholars have been expressing different opinions to define one single order in which to organize hexadic and decadic sign relations and the corresponding derived categories. As I have mentioned, there has been no agreement on the order, partial or strict, of the elements of hexadic and decadic sign relations. Hardwick (1977) footnoted that the order became a matter of opinion. Figure 4.46 depicts the approximate orders which some authors have proposed as the correct ones. The order is approximate because several authors have connected the *explicit* interpretant with the *final* interpretant, and the *destinate* with the *immediate* one, which swaps their order. This is in contradiction of Peirce's explanation (Peirce and Welby-Gregory, 1977, p 11), but this contradiction seems overlooked by the community.[52]

Weiss and Burks (1945, p 385-6), Sanders (1970, p 7), Hardwick (1977) Jappy

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[52] From I what could perceive Weiss and Burks (1945, p 385) and Hardwick (1977, p 162) mislabelled destinate and explicit interpretants with immediate and final, respectively. This mislabel has been perpetuated in the literature (Ryan, 1993, p 217-21).

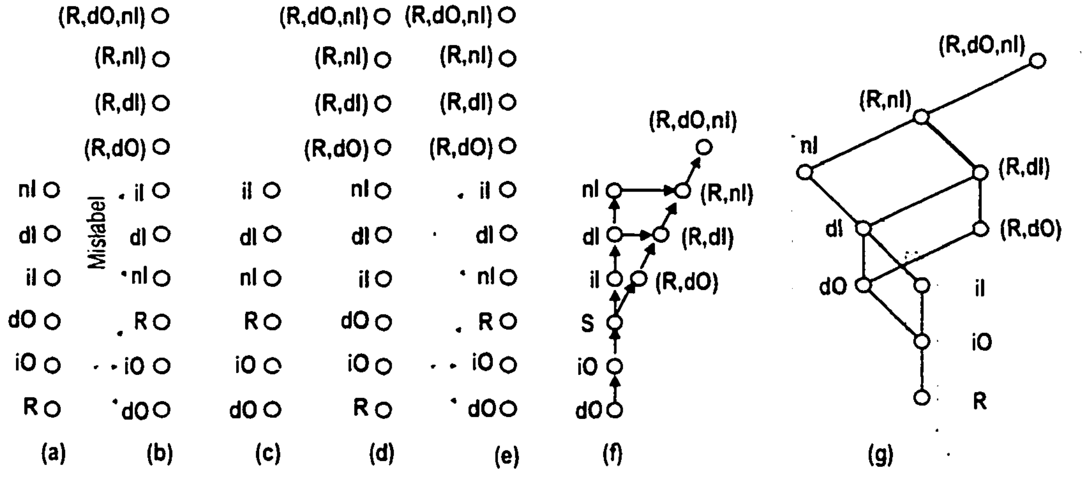

Figure 4.46: **Enumeration of Peirce's hexadic and decadic sign relations:** There is no agreement on the sequence, or partial order, in which a sign relation should be organized. (a) Peirce (1958, CP 8.343) (b) Peirce and Welby-Gregory (1977, p 84) (c) Hardwick (1977, p 162-3) (d) Weiss and Burks (1945, p 386-7) (e) Müller (1994, p 138-43) (f)Jappy (1983, p 147) (g) As proposed here

(1983). Ryan (1991, 1993), and Müller (1994) have discussed or used different enumerations of the decadic sign relation. In Figure 4.46, I give some examples of different enumerations found in the literature. A brief commentary is important to illustrate the challenge that lies ahead. For example, Marty (1982, p 179) initially listed the subdivisions of the sign as ($O_d \to O_i \to R \to I_i \to I_d \to I_f$) swapping the final and the immediate interpretant. Marty later modified the order to ($O_d \to O_i \to R \to I_f \to I_d \to I_i$) (Marty, 1990, p 221), justifying this by appealing to Peirce's comments that an element *determines* another (Marty, 1990, p 210). Jappy (1983) attempted to amend the hierarchy through a reformulation but maintained representamens presupposing objects.

I believe that a single passage in which Peirce textually ordered the hexadic and the decadic sign relations starting with the dynamoid Object[53] should not be taken as the archetype of the correct strict order used to organize the corresponding categories.

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[53] The passage has been quoted above (Peirce and Welby-Gregory, 1977, p 84).

From my perspective Peirce was saying that a subdivision *categorically presupposes* another (e.g. thirdness presupposes secondness) and not that a subdivision *chronologically determines* the next subdivision.

In fact, there is other evidence in Peirce's work that Representamens do not presuppose Objects, at least in the derivation of categories, as some of the authors have assumed. From a structural or syntactical perspective, it is possible to affirm that some of these proposed enumerations are not in accordance with Peirce's work. I repeat, Peirce said that these categories were open to future exploration. If Peirce's hypothesis corresponds to actual semiosis, however, it is a matter that demands future interdisciplinary research and is outside the scope of this thesis.

Peirce discussed the combination between the first two trichotomies through the correlation between the sign itself and the immediate object ((potisigns, actisigns, famisigns) correlated with (descriptives, designatives, copulants)). See Figures 4.11(c) and (d). The precedence of the representamen over the immediate object is clear, otherwise a different set of categories would be the valid ones (Peirce, 1958, 8.350-65).[54]

I have illustrated with Figure 4.39 how a different set of classes is derived from ternary sign relations organized with different orders among its elements. The case of decadic sign relations is similar. Indeed, triangular tables (collapsed trees) do not clearly depict the semantic differences, even if restricted to sixty-six classes.

In the sequel, I employ spatial Hasse diagrams to show the implications of distinct enumeration within a sign relation. Distinct sequences may be a result of different ways to enumerate the components of a sign relation. Just as the correlation derived from ternary sign relation is represented ions (projected on a 2-dimensional surface), hexadic and decadic sign relations demands 6- and 10-dimensional spaces, also projected on a 2-dimensional surface. I limited the illustrations to a six-dimensional subspace. This is the subspace of the ten-dimensional space necessary to depict the

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[54] The results that Peirce arrived at are also clear evidence that the representamen precedes the immediate objects (the immediate object presupposes the representamen), contradicting some proposed enumerations in which decadic sign relations start with the dynamic objects.

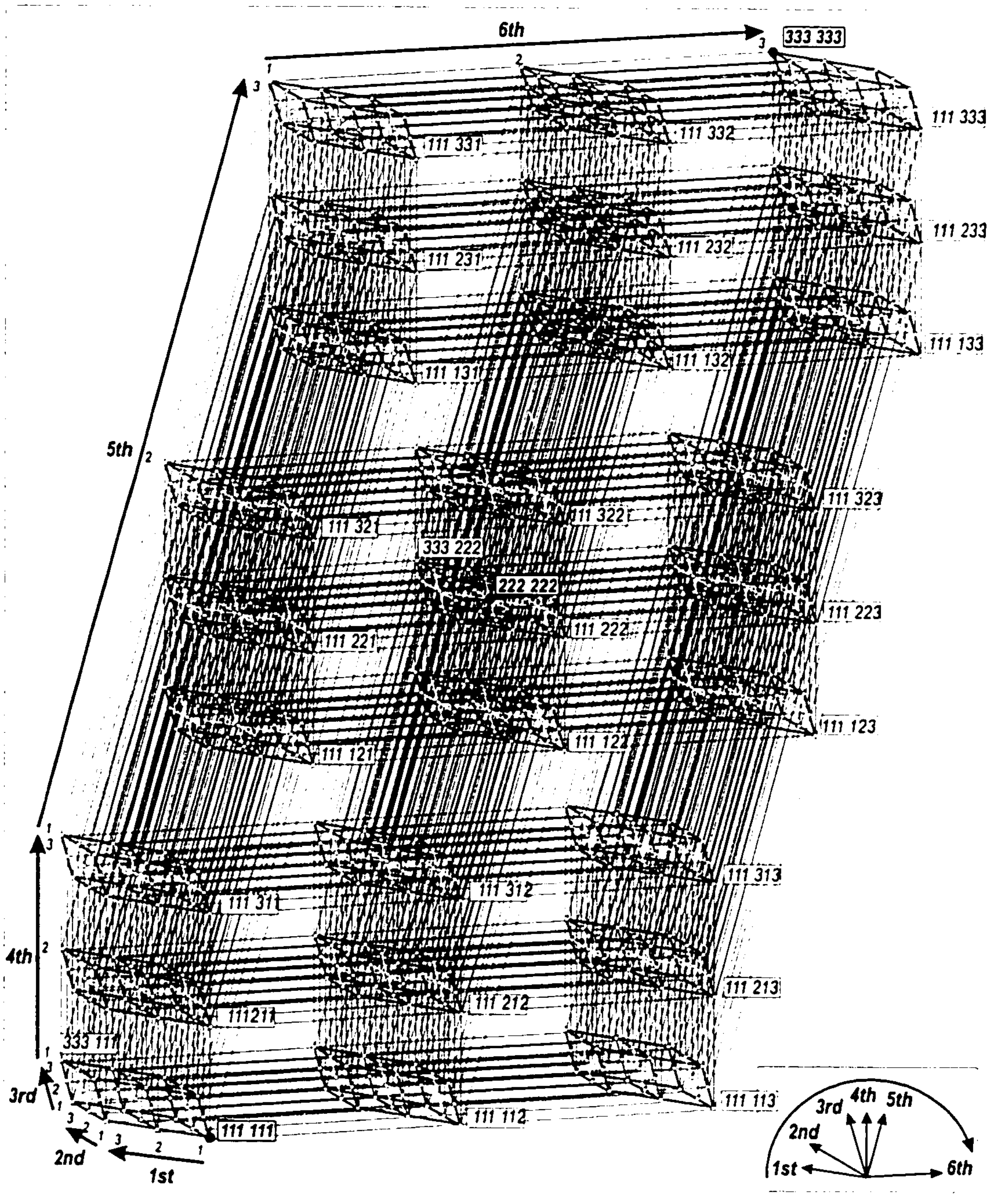


Figure 4.17: **Lattice with the 729 combinations derived from an hexadic relation**

categories of a decadic sign relation.

To begin, the Hasse diagram in Figure 4.47 depicts the 3^6 (729) arrangements derived from an hexadic sign relation assuming no order constraint among them. In Figure 4.47, I have chosen the proportions and dimensions of the six axes (six trichotomies) in order to cluster the relations among the first three trichotomies in contrast with the relations among the last three. In the spatial organization of the diagram it is possible to identify nine smaller parallelepipeds, which correspond to the first three trichotomies (1st, 2nd, 3rd). The last three shape the diagram as a whole, because they presuppose the former three. I have also labeled some elements (indexes) to illustrate the coordinates of possible arrangements.

A constraint such as a strict order among the elements would delimit a region in this six-dimensional subspace containing twenty-eight elements. This is exactly the number of categories Peirce speculated for hexadic sign relations. For example, Figure 4.48 illustrates the categories derived from the hexadic sequence $1st \rightarrow 2nd \rightarrow 3rd \rightarrow 4th \rightarrow 5th \rightarrow 6th$. In my interpretation this would correspond to Peirce's $(R \rightarrow iO \rightarrow dO \rightarrow iI \rightarrow dI \rightarrow nI)$ enumeration.

As I have shown for the ternary sign relation, a different sequence would result in distinct sets of derived categories. I developed the Hasse diagram in Figure 4.49 to contrast the two sequences that are most often diffused in the literature, which correspond to $(R \rightarrow iO \rightarrow dO \rightarrow iI \rightarrow dI \rightarrow nI)$ and $(dO \rightarrow iO \rightarrow R \rightarrow nI \rightarrow dI \rightarrow iI)$. In relation to each other, the first three trichotomies are inversely ordered. The "cuts", as illustrated before in the three-dimensional case, delimit different regions, consequently different sets of categories.

I consciously leave for a future work the development of a diagram considering sign relations as lattices. I have not developed an illustration for a set of categories which considers all the valid enumerations of a sign relation. If all the valid sequences within that partial order were considered, the derived set would include the conjunction of all corresponding categories. In other words, there will be more valid classes than the sets derived from only one enumeration.

Spatial Hasse diagrams are an alternative, but should not be seen as the only

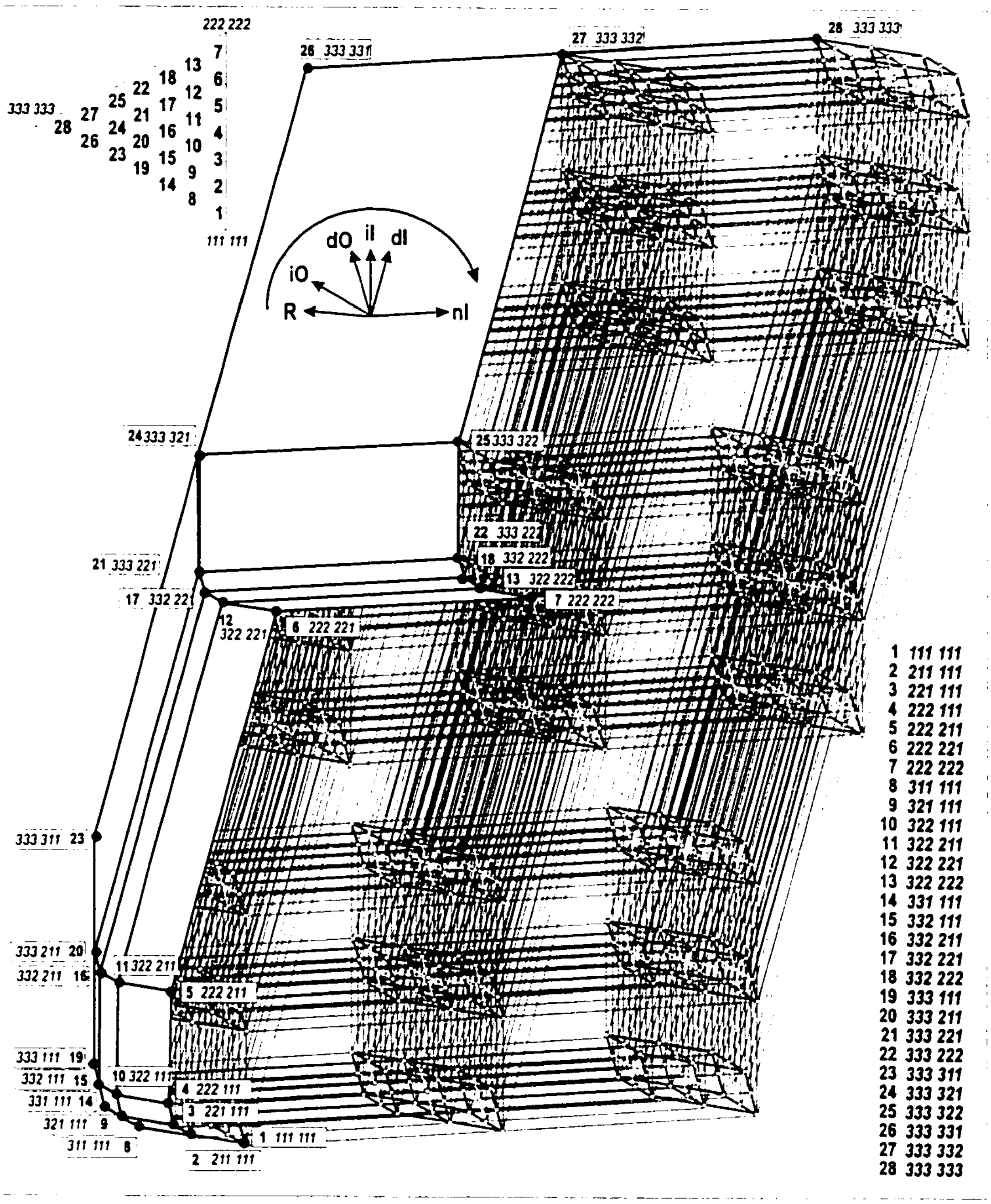
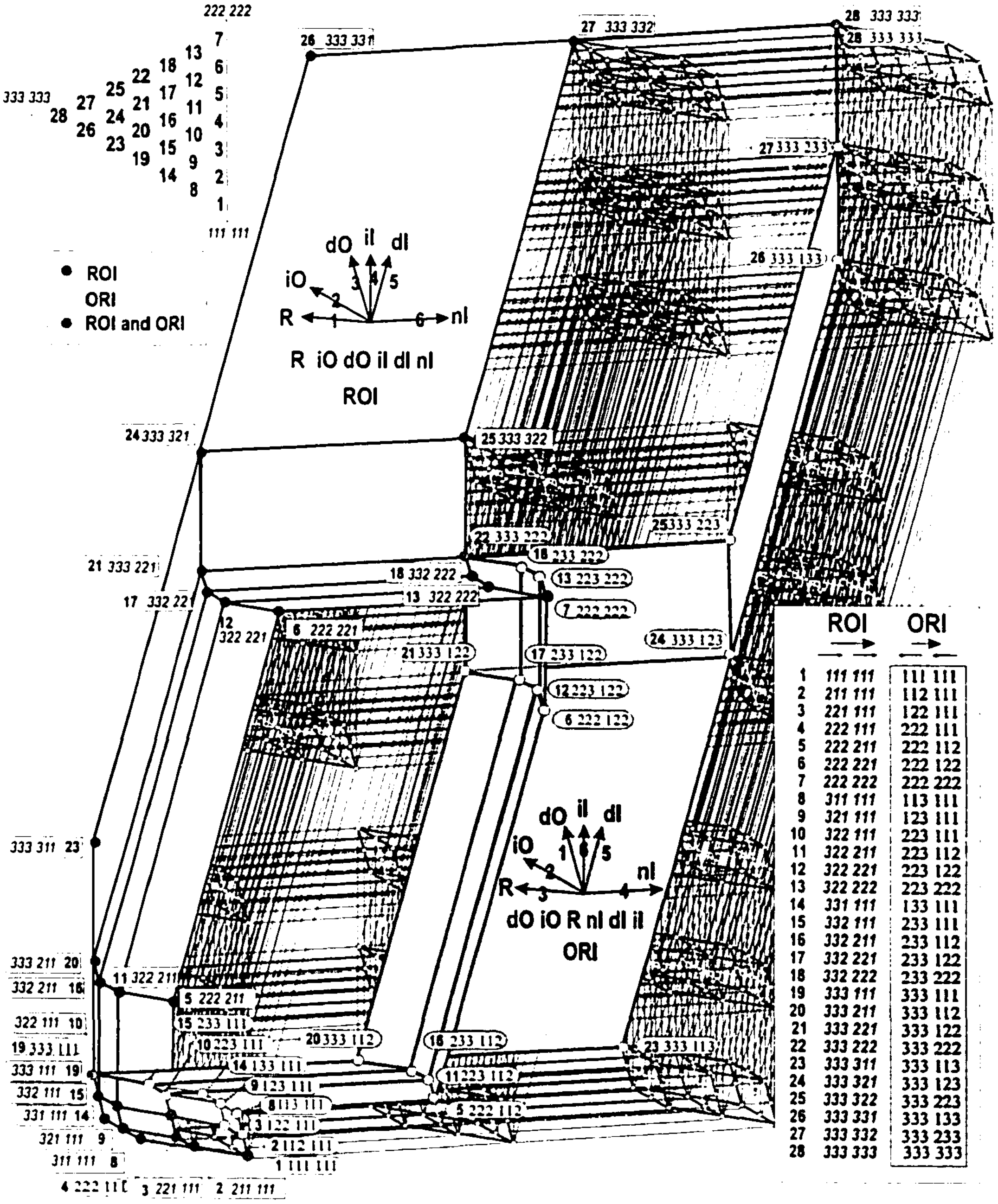


Figure 1.18: **Hasse diagram of the twenty-eight categories:** derived from ($R \rightarrow iO \rightarrow dO \rightarrow iI \rightarrow dI \rightarrow nI$)



	ROI	ORI
1	111 111	111 111
2	211 111	112 111
3	221 111	122 111
4	222 111	222 111
5	222 211	222 112
6	222 221	222 122
7	222 222	222 222
8	311 111	113 111
9	321 111	123 111
10	322 111	223 111
11	322 211	223 112
12	322 221	223 122
13	322 222	223 222
14	331 111	133 111
15	332 111	233 111
16	332 211	233 112
17	332 221	233 122
18	332 222	233 222
19	333 111	333 111
20	333 211	333 112
21	333 221	333 122
22	333 222	333 222
23	333 311	333 113
24	333 321	333 123
25	333 322	333 223
26	333 331	333 133
27	333 332	333 233
28	333 333	333 333

Figure 1.19: **Hasse diagram with two sets of twenty-eight derived categories**: (a) ($dO \rightarrow iO \rightarrow\rightarrow R \rightarrow nI \rightarrow dI \rightarrow iI$) in white, and (b) ($dO \rightarrow iO \rightarrow R \rightarrow nI \rightarrow dI \rightarrow iI$) in darker gray.

alternative. I illustrate in the next subsection how trees and triangles can be used to depict these restricted subsets of categories.

4.5.2 Comments on other existing diagrams

Trees and triangles (collapsed trees), as I have shown before are not the best choices to visualize the relations between the categories. Indeed, there is no place in a triangle for the categories other than those derived from a single enumeration. I decided to append this subsection, with its illustrations, because the literature discusses extended triangles as viable alternatives to depict sets of categories.

Although I find them inappropriate to visualize the derivation of categories, that is my judgement, and I cannot force this decision on the involved community. Moreover, the contrast can contribute to a deeper understanding of the whole topic.

The tree that would connect the sixty-six categories derived from a single enumeration of the components of a decadic sign relation is illustrated in Figure 4.50. Sanders developed an arborescent diagram similar to this one to illustrate the number of derived categories from different sign relations (Sanders, 1970, p 6).

Similar to the triangle that illustrates the ten categories derived from the ternary sign relation, a triangle depicting the sixty-six categories derived from the decadic sign relation can be obtained through the collapse of the tree represented in Figure 4.50 onto a plane. Figure 4.51 depicts the corresponding triangular diagram as a collapsed tree. It is possible to obtain the corresponding indexes of the sixty-six categories through a traversal of the collapsed tree. The indexes on the diagram are independent of the semantics of the strict order of the subdivisions of a sign.

A similar diagram depicted in Figure 4.52 can be used to illustrate Weiss and Burks's formula for calculating the number of derived categories of a certain n-adic sign relation that is assumed strictly ordered. The formula is similar to the formula of the area of a triangle, but considers its discrete nature. Weiss and Burks (1945, p 387) wrote that "in general, n trichotomies yield [...] $(n+1)(n+2)/2$ classes.". This can be visualized with the aid of a triangle, in which the level corresponds to the number of available trichotomies.

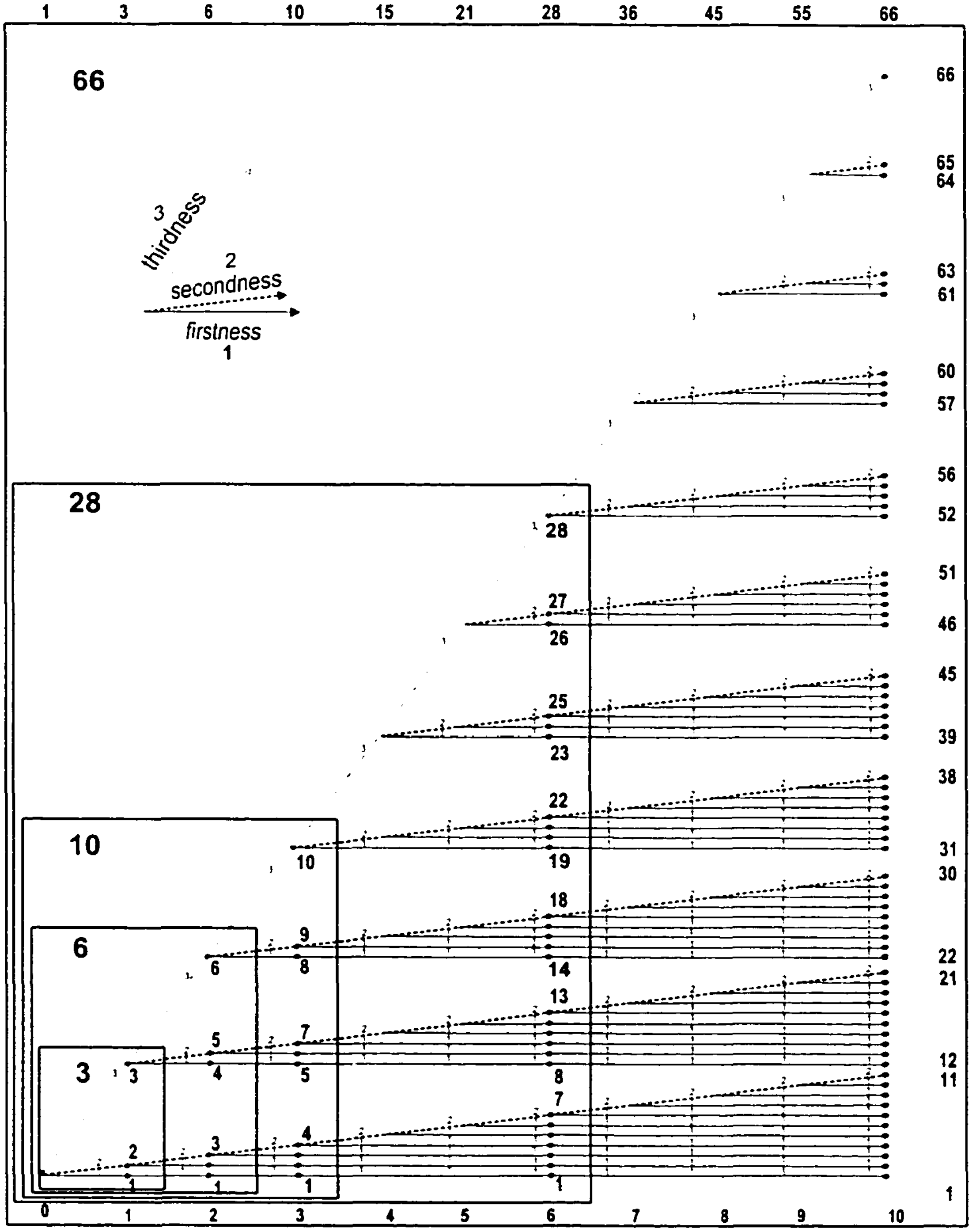


Figure 1.50: **Deriving tree for the sixty-six valid categories**

Peirce introduced hexadic and decadic sign relations as refinements of ternary sign relations. A research topic that has generated some interest is associated with the relations among sets of categories derived from differently composed sign relations.

A mapping between the several sets of derived categories should first establish the conventions about how to perform this mapping. The mapping of one set of derived categories onto the other have been addressed by Marty (1990, p 225) and by Maróstica (1992), cited by Farias and Queiroz (1999, 2000b).

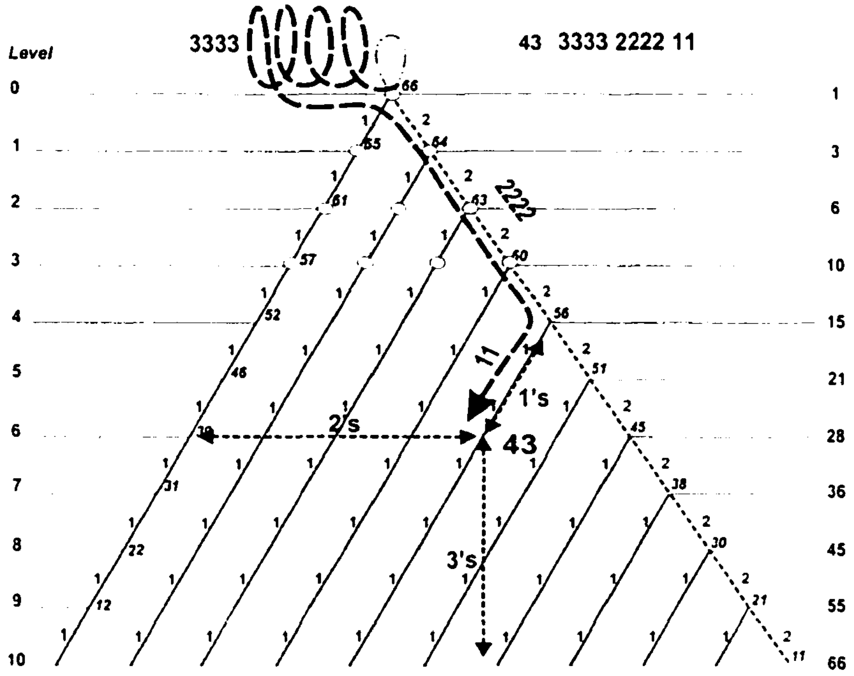


Figure 4.51: **Collapsed tree of the sixty-six categories onto a triangle**

Farias and Queiroz (1999, 2000b) also used extended triangles to compare sets of categories. As I have shown in Figure 4.39, sets derived from different enumerations of sign relations's components, are semantically different. I understand that the use of triangles to group different categories is limited to one subset of the derived categories of a sign relation. If the sets do not coincide with the objects represented in the triangles, the groups should not be compared, otherwise it would be semantically inconsistent.

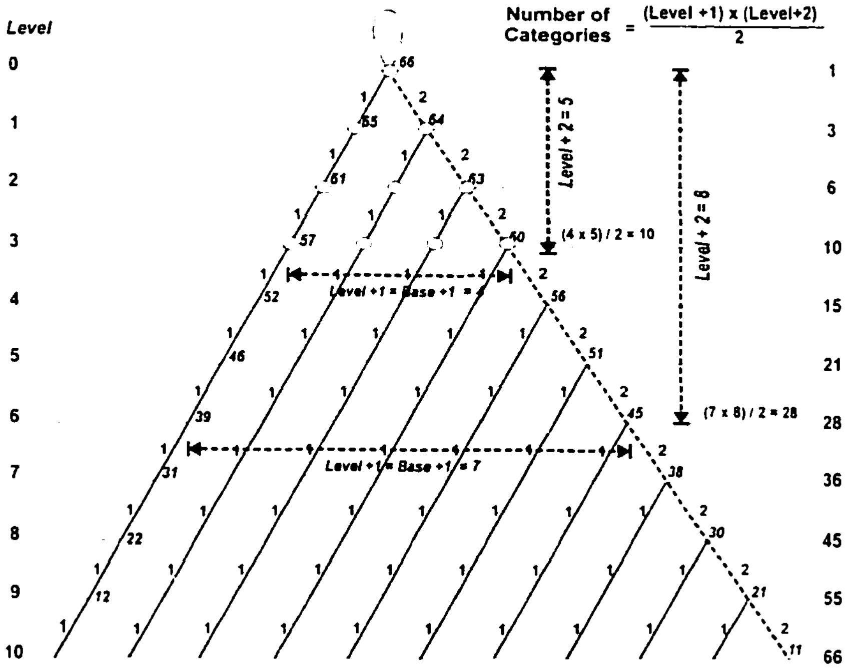


Figure 4.52: **Number of Categories of an n-adic sign relation**

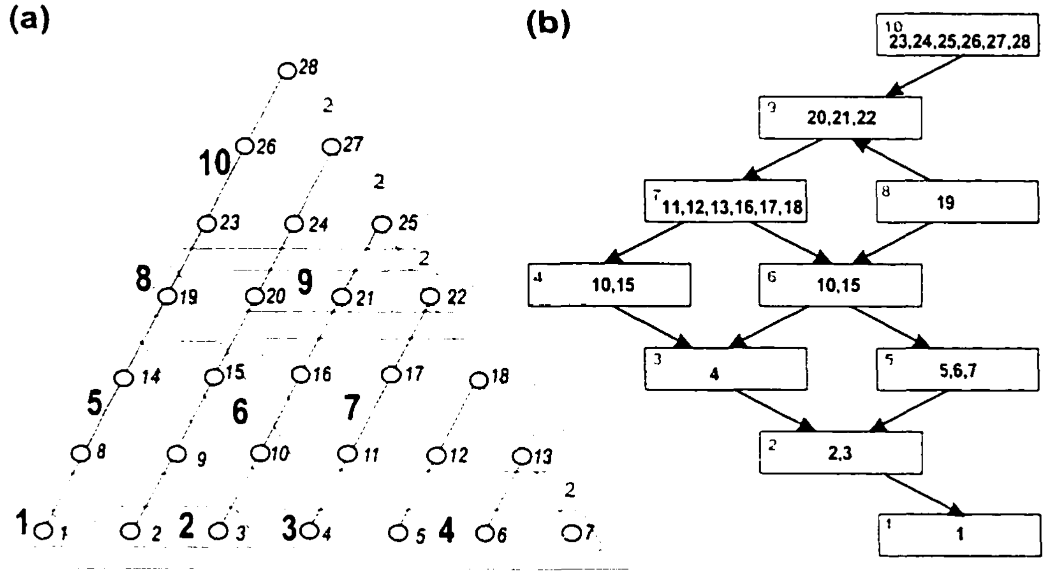


Figure 4.53: **Marty's relation between twenty-eight and ten categories**

Marty related sets of categories derived from ternary and hexadic signs (Marty, 1990, p 228). The sets he compared were derived from strictly ordered signs based on ($dO \rightarrow R \rightarrow nI$) and ($dO \rightarrow iO \rightarrow R \rightarrow nI \rightarrow dI \rightarrow iI$) relations. Marty's enumerations of decadic sign relations are not the ones I understand to be the ones in accordance with Peirce's work, but they are consistent with each other. He proposed a diagram similar to the one illustrated on Figure 4.53(b) to relate two sets of categories.

I have regrouped his mappings using the triangular diagram depicted on Figure 4.53(a). I remark that Marty enumerated the categories in the inverse order to Peirce, ascribing 28 to (111 111) and 1 to (333 333). However, Marty named the ten classes according to Peirce's ten classes, which are derived from a ($R \rightarrow O \rightarrow I$) relation of order. In the diagram, I have relabelled them inversely.

I have not explored how to compare two sets of derived categories derived from sign relations with distinct cardinality. I understand that before exploring such a theme, it is necessary to achieve consensus on more fundamental matters.

I conclude this last chapter hoping that the diagrams and structures I have presented in this chapter will contribute to the development of semiotics, to the organization of sign relations and their categories, and the cross-pollination with Informatics.

4.6 Summary and Final Remarks 4

In the history of HCI and informatics, the social sciences have contributed to human-centered perspectives through disciplines such as psychology, anthropology, and sociology. However, the disciplines that have studied human communication for the longest are not the ones in the social sciences, but the ones in the arts and humanities. Languages have been key to the development of informatics. Similar to the development of linguistics and language studies, this contribution has emphasized only language structure, rather than both structure and use. However, a broader understanding of human communication in informatics, one that includes language use, has received scant recognition until now. In this thesis, I only point to this unexplored subject.

I understand that the cross-pollination between informatics and semiotics will be feasible only if the participant fields are able to establish a common ground across the complementarity of their differences. The challenge is that there has been no common ground regarding what communication is in either field.

Through the research I have carried out in this dissertation, I realized that it was not enough to import models of communication that have been developed in the arts and humanities if these models were as stiff as the ones developed and used in informatics and the cognitive sciences. In semiotics, there has been a strong tendency toward linear sequential models. Peirce went beyond this tendency, but has not been well understood. Today, there is no agreement on how to represent a sign relation. I am not talking about the rivalry between different schools: even within schools, confusion reigns on how to organize the components of a sign relation syntactically.

Instead of scanning across different topics across HCI and informatics, I explore a topic that is related to the fundamentals of Peirce's Systematic Philosophy. The main contribution of this chapter is a systematization of a fundamental problem in semiotics, that is, how to structure the unity of analysis of semiotic processes, which is the sign relation. Peirce is considered to be a forerunner in the development of semiotics as understood today. His work is also considered a precursor to pragmatism. The size and diversity of Peirce's writings is challenging. But within a wild heterogeneity, very coherent principles structure the subdivision of the several areas of his work, and what they presuppose.

In the last fifty years, Informatics has developed a series of concepts, tools, processes, methods, theories, etc. to organize the components of artifacts or systems it produces. I am using some of these elements to organize sign relations systematically. In particular, I discuss partial orders in Charles Sanders Peirce's triadic and decadic sign relations. The tools I am referring to are in the scope of data structures, discrete mathematics, and engineering. They include trees, tables, posets, lattices, and Cartesian Coordinate systems. The use of such tools to explore semiotic relations may be a small step, but in my understanding, it is a necessary one to establish an initial common ground.

It is feasible for people in informatics to contribute to semiotics with a systematization of its notation because most of the theory in informatics has been of a monadic nature, what coincides with its emphasis on syntax. Dyadic and triadic models, which could be correlated with the semantic and the pragmatic have not been explored to the same extent.[55] For example, most of the semantics studied in Informatics refer to objects within the computer. Within a Peircean perspective, the understanding of "meaning" necessarily triadic. Semantics and pragmatics, if extended to be in consonance with Peirce's philosophy, involve fascinating subjects which need to be pursued in order to ground design as a meaningful communicative activity theoretically, practically, and ethically. My intention is to develop these implications across my future professional practice as an educator.

I conclude this chapter with a quote from Herbert Simon. In 1995 he wrote an article in a special issue of the Stanford Humanities Review. The issue discussed the gap between the Cognitive Sciences and Literary Criticism. Simon expressed his thoughts about the possible contributions and the actual debts of the cognitive sciences to literary criticism in the following passage:

1995 Herbert Simon *Literary Criticism: A cognitive Approach* (Simon, 1995)

In this paper, I will be acting as an unabashed missionary for contemporary cognitive science, [...] which is itself an amalgam of artificial intelligence, cognitive psychology, and linguistics, with a few other trace substances (e.g., anthropology, epistemology) thrown in.

I will argue that cognitive science has reached a point in understanding human thinking where it can say a great deal about literary criticism; in particular, that it can cast some light on the theoretical foundations of criticism and even generate useful advice for its practice. But my position is not as asymmetric as these words would make it appear.

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[55] Although semantics and pragmatics have been construed in very different ways a careful analysis of Morris, triangle shows that these terms have been introduced as dyads, and not as triads, which is in contradiction to Peirce's model.

> Written texts, literary and other, provide a rich source of data for understanding cognition. Enormous thought goes into the production of texts and perhaps even more (given the ratio of readers to writers) into interpreting them. These data have not been much mined by cognitive scientists, who therefore have much to learn from literary criticism, which examines the texts in depth. Perhaps what I am attempting here should be viewed as a gesture from the cognitive side to repay a small part of the debt we owe to critics and theorists of criticism for introducing us to literary texts. [...]
>
> The paper may also be viewed as an experiment in communication between the two cultures of the humanities and the sciences. I simply take for granted that, pace Leavis, there are two cultures, much as C. P. Snow (1959) described them thirty years ago, and that communication between them is infrequent and then, when it occurs, noisy. I also take for granted that it is important for our society that this communication be improved substantially.

Informatics can benefit from the knowledge developed in Semiotics, and vice versa, but the communication will be very noisy and truncated until the communities are able to develop a mutual appreciation for the different perspectives they sustain.

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Chapter 5

Looking Across and Looking Along: Reflections

> The categories according to which a group envisages itself, and according to which it represents itself and its specific reality, contribute to the reality of this group.
>
> Pierre Bourdieu, *Language & Symbolic Power*, p 133, 1991

> Well intentioned professionals (those who use invasion not as deliberate ideology but as the expression of their own upbringing) eventually discover that certain of their educational failures must be ascribed, not to the intrinsic inferiority of the "simple men of the people," but to the violence of their own act of invasion. Those who make this discovery face a difficult alternative: they feel the need to renounce invasion, but patterns of domination are so entrenched within them that this renunciation would become a threat to their own identities. To renounce invasion would mean abandoning all myths which nourish invasion, and starting to incarnate dialogical action.
>
> Paulo Freire, *Pedagogy of the Oppressed*, p 137, 1970

Informatics is about technology. Therefore, potentially, it could be about techne and logos. *Techne* comes from the Greek, and meant *art, craft,* a human skill grounded "in general principles and capable of being thought" [Cambridge Dictionary]. It could also be about information from *informare*, that in Latin construes as "to give form to, to describe" (ibid).

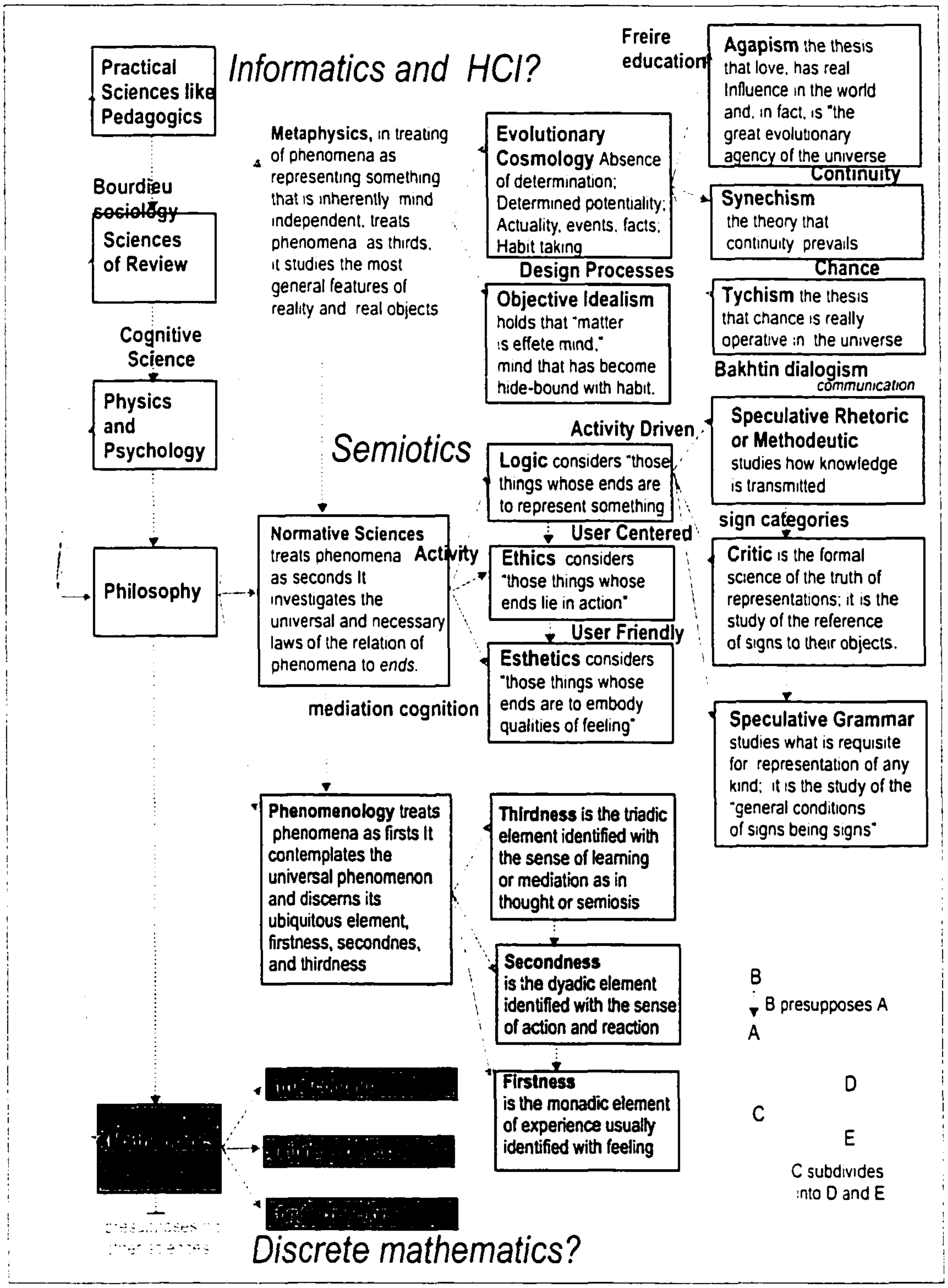
Linking techne and logos, this thesis is about how Informatics has given, is given, and could give form to the general principles of the art and craft of computing. It is about how stakeholders reflect on and intervene upon computational phenomena. The loss of an important file, dream of an intelligent computer, avoidance of a Automated Teller Machine machine due to illiteracy, joy of winning in a computer game, sore back and wrist, meaning of receiving a message from a missing close friend through e-mail, replacement by a robot, all drive different sorts of people to structure their professional lives in consonance and dissonance with everyday culture. This thesis is about people, and their activities, attitudes, values, and world views. It is also about critically reflecting on the the good, the bad, and the ugly facets of informatics, on how their blurred boundaries have been co-constructed across theories, practices, and praxis in different disciplines, and on how to describe this complex cultural ecology.

As I was writing these conclusions, I was wondering on how different I would have written this thesis if I had been somewhere else. The main topics of the four chapters would still be present, but probably in a different order and depth. An historical account of Informatics would still be crucial for a critical understanding of where Information Technology is coming from. A discussion on Human-Computer Interaction tendencies would also foster awareness for the future scope of Informatics. Design would continue to link where we come from to where we are going. As a common thread, models in Informatics, HCI, and Design would also be explored in the light of Peirce's work, whose rationale is systematized in a chapter on Semiotics, which could be the first one.

In consonance with Peirce's work the general principles that fostered the development of several conceptual models across this thesis was that thought and action deeply interpenetrate each other across multiple dimensions. I have chosen to explore Peirce because the rationale behind his philosophy goes consistently beyond dichotomously structured understandings of the world, from Mathematics to Practical Sciences, passing through Semiotics. Peirce not only blurred dichotomies, but provided a scaffold to bridge beneath, across, and beyond their isolated falsely presumed nature. In particular, the concepts of mediation and of thirdness could play key roles in overcoming traditional categories that organize not only Informatics, but also Academia and society. They go beneath and beyond because they attempt to explain dichotomies as a possible states of mind/world. In Peirce's Semiotics people are not limited to secondness. When they think/act purposeful and responsibly, they are in thirdness, what also includes secondness. Peirce's criticisms are in consonance with other authors for whom mainstream approaches of cognition and communication were too limited to explain their historically multifaceted nature, such as Mikhail Bakhtin, Pierre Bourdieu, and Paulo Freire. I have not explored their work in this thesis, but I have listed some related work in Appendices D and E.

Some related comments are appropriate, and I will develop them in these concluding remarks with the aid of both Figure 5.1, first introduced in the preface, and Figure 5.2, which depicts the core conceptual frameworks proposed across this thesis. The link between, which is not evident in the previous chapters, is briefly discussed below.

Figure 5.1 graphically emphasizes what are the sciences or disciplines discussed and often proposed by Peirce that presuppose Semiotics (Logic) and the ones that are presupposed by it. Semiotics is depicted at the center of Figure 5.1. On one hand, mainstream Informatics has developed theoretical depth in the mathematical facets of the form and structure of computational phenomena (bottom). On the other hand, it has also developed breadth in its actual consequences across society, but not at the same depth (top). In other words, the underpinnings and theoretical tenets of mainstream Informatics are not yet ready to account for the footprint of its social and ethical actual implications and consequences. Metaphorically, mainstream Informatics' reflective frameworks are still mainly focused on wood, being not powerful enough to envision or either see the tree or the forest. To be fair, different branches



Metaphysics, in treating of phenomena as representing something that is inherently mind independent, treats phenomena as thirds, it studies the most general features of reality and real objects

Evolutionary Cosmology Absence of determination; Determined potentiality; Actuality, events, facts; Habit taking

Agapism the thesis that love, has real Influence in the world and, in fact, is "the great evolutionary agency of the universe

Synechism the theory that continuity prevails

Objective Idealism holds that "matter is effete mind," mind that has become hide-bound with habit.

Tychism the thesis that chance is really operative in the universe

Speculative Rhetoric or Methodeutic studies how knowledge is transmitted

Logic considers "those things whose ends are to represent something

Normative Sciences treats phenomena as seconds It investigates the universal and necessary laws of the relation of phenomena to *ends*.

Ethics considers "those things whose ends lie in action"

Critic is the formal science of the truth of representations; it is the study of the reference of signs to their objects.

Esthetics considers "those things whose ends are to embody qualities of feeling"

Speculative Grammar studies what is requisite for representation of any kind; it is the study of the "general conditions of signs being signs"

Phenomenology treats phenomena as firsts It contemplates the universal phenomenon and discerns its ubiquitous element, firstness, secondnes, and thirdness

Thirdness is the triadic element identified with the sense of learning or mediation as in thought or semiosis

Secondness is the dyadic element identified with the sense of action and reaction

Firstness is the monadic element of experience usually identified with feeling

Figure 5.1: **Future work in relation to Peirce's Systematic Philosophy**

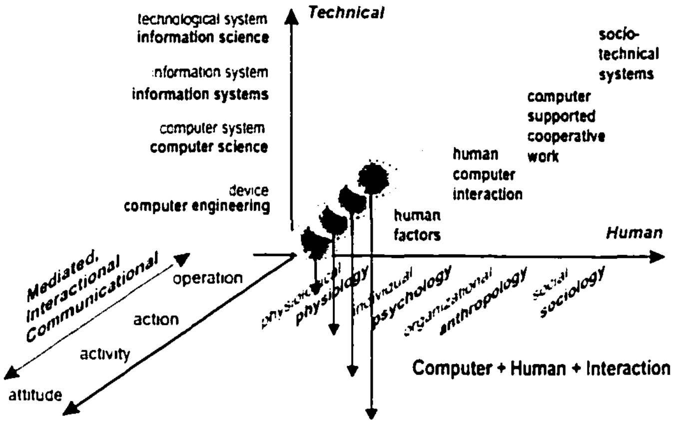
of Informatics vary in scope on how they see the trees. The long term goal of this thesis is intended to raise awareness of the fact that the wood depends on the tree and the forest, and vice-versa.

It is in my expectations that a future and mature Informatics would take into account the consequences of its professional interventions, theoretically, practically, and politically. This is not yet the case, but a myriad of endeavors have already started to look to Information Technology, and its outcomes (e.g. computers), as if it were open to its environment, as if its artifacts were interactive and mediatory.

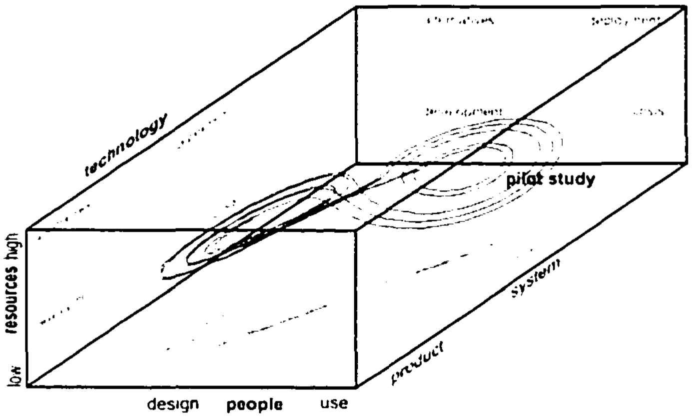
The conceptual space depicted in Figure 5.2(a), whose facets are introduced and discussed across Chapters 1 and 2, is intended to describe some of the disciplinary scope across which a broader understanding of Informatics can be explored. The main rationale that informs and structures this framework is ternary, and correlates human, computational, and interactive aspects of human action and the related disciplines that study them. This framework, or conceptual space, is expressive enough to describe disciplinary niches and interdisciplinary relations among activities and disciplines.

Chapter 3, on design processes, was intended to describe the dynamics of disciplinary niches abstractly, such as the ones that link solid state physics, computer engineering, computing science, information systems, information science, and the general public. Most process models across these disciplines remain limited to the scope of their own niches of expertise, assuming that professionals of other disciplines would complete what is not their responsibility within the established socioeconomic order. Most professionals tend not to question where professional demands come from and where they lead to, and this is reflected in the process models that structure their daily activities. For example, developers usually do not critically reflect on the relation between requirements and usability. They indeed structure their professional identities as people that perform those kinds of activities. Linear models of professional workflow (e.g. design process models) abound, but are not capable of reciprocally tieing demand and production. Indeed most models across Informatics have constellations of interests focused on Information Technology production, rather

(a) HCI's conceptual space and its niches



(b) Design processes as a proposed niche dynamics



(c) Process of inference as trajectories in Peirce's categories

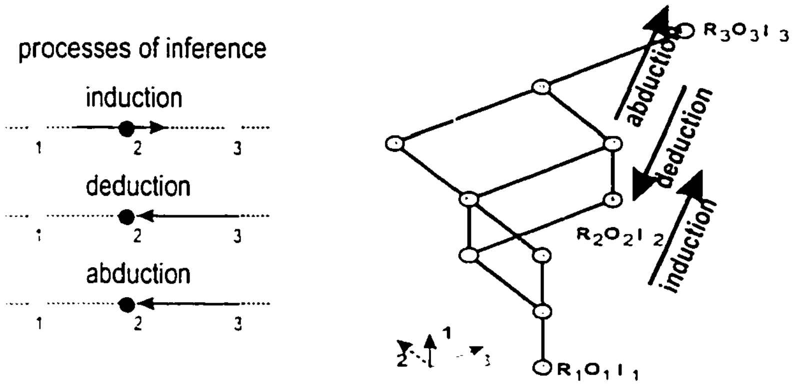


Figure 5.2: **Main frameworks proposed across the thesis**

than use. This can be described with the aid of similar diagrams as the one depicted in Figure 5.2(b), which visualizes participatory prototyping design process.

Peirce's work also sheds light on the development of this model, which is in accordance with a ternary (Semiotics and Phenomenology) understanding of design processes. It goes beyond most previous models found in the literature, which were dichotomously, linearly and unidirectionally organized. It seems also to be in accordance with part of Peirce's Evolutionary Cosmology, as I explain in the sequel. The process model, fortuitously visualized with the aid of the Lorenz attractor, illustrates (a) the absence of determination through its non-repeatable trajectory, (b) its potential determination with its repeatable but non-periodic pattern, and (c) its habit-taking characteristics as the centripetal and centrifugal forces that attractors can have.

Peirce was not the only one who went beyond traditional models. Other authors have explored with different emphases related problems. I would like to explore in my future work the relation between design and use also in the light of (a) Mikahil M. Bakthin's concepts of heteroglossia (multifaceted), chronotope (centrifugal and centripetal forces), alterity (difference), utterance (dependence on historical and situated conditions), and other concepts of his philosophy of language; (b) Pierre Bourdieu's concept of field and habit, and their relations to orthodox and heterodox forces across societies, as well as his plural concept of capitals, which correlates cultural and material wealth across professions, as well as his reflexive sociology; (c) Paulo Freire's work on progressive education which criticizes dichotomies that separate thinking from doing, teaching from learning, oppressing and oppressed, and so on; and (d) the roots of Pragmatism, including the work of Peirce himself and John Dewey, in which the concept of action is key to education, as it was for Peirce's Semiotics.

As I explored Semiotics as a possible reflective scaffold for Informatics, I understood that there were not much agreement on its foundations. Therefore to accomplish my goal in a sound way it was necessary to clarify its rationale. Peirce's Philosophy (center) investigated the necessary and universal relation between means to *ends*. This implies purpose, resources, and intention. I doubt that people in traditional Informatics would say that their computers have no purpose. They are aware of the footprint of their professions, and the responsibility towards it. What they are usually not aware of is that the way they think about computing keep these issues out of their concerns.

Awareness for these problems within Informatics have raised renewed interest in Semiotics and other approaches that understand language and interaction in more comprehensive ways than Formal Languages/Lingusitics do. Peirce's Semiotics was part of his philosophy, and had as its close roots Ethics and Esthetics. It was exactly through this relational approach that Peirce attempted to overcome deeply rooted dichotomies through the concept of sign, in its many variants and categories. Representations, as habit, presuppose action and perception.

It is enough to say that in his work discussions on signs and categories are usually accompanied with discussions on sign processes (semiosis) and degenerate signs, which emphasize their relational characteristics. Peirce's Semiotics was subdivided into three branches, to which he gave different names across his long career. Methodeutic studied knowledge transmission. Critic studied the truth of representation. Speculative Grammar studied signs as signs. The concepts of Syntax, Semantics, and Pragmatics can be correlated with Peirce's semiotics but were organized differently in relation to the structure of sign relations. While Peirce's subdivision is thoroughly triadic, Morris is dyadic. See Figure 4.2(e), in Chapter 3.

Mainstream theoretical Informatics have been studying computers as computers, as syntax, and studying everything else as such. However, some approaches such as HCI and Software engineering have been concerned with the actual effectiveness of Information Technology use (computers + users) and computer construction (computers + designers), respectively. Still others have been exploring computers as means, as mediations, as signs, and these are usually the approaches that make reference to language studies, including Peircean Semiotics and Cultural Historical Activity Theory.[1] While Peirce's semiotics emphasizes the sign, presupposing action,

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[1] See Appendix E for references. Engeström's expansive learning cycle, used as an example of scope in contraposition to the IDEAL model, is an example depicted in Figure 3.29.

Activity theory emphasizes activity and outcome, presupposing sign, or tools. In the cultural ecology of Informatics, they have therefore different but complementary foci. That is a topic, not explored here, that could foster a deeper cross-pollination between Semiotics and the Cognitive Sciences.

Most disciplines, however, have stratified their interests across different levels of hierarchies that are assumed independent of each other. In Peirce, they have an inclusive nature, and this is clearly stated as relations of presupposition, as depicted in Figure 5.1. If one understands a sign as action, it is more difficult to fall in the tar pit of either taking the wood for the forest, or imagining a forest without trees. This is not well understood across the literature. Indeed, the same criticisms that I have for the reductionist scope of Informatics I have for Semiotics. This relational and encompassing nature of Peirce's work is not always emphasized by the work of Peirce's followers, with exceptions, who apply his signs and his categories of signs as mere classificatory existential schemata, stratifying and isolating what is enclosed and deeply linked.

At this point in the development of the thesis, I had two alternatives. Firstly, I could have continued with the breadth-first approach exploring areas that have been exploring Semiotics in Informatics. Secondly, I could explore the rationale of Peirce's work in terms of relations. I decided for the second option, because I found that most approaches, although they were explored uncharted terrain and were evidence that the research direction was interesting, were not in agreement with Peirce's framework, at least in my understanding. I do not assume that Peirce is right or wrong. I should also emphasize that I explored neither the conditions of truth of Peirce's Semiotics nor how it has been transmitted, which is a topic of great importance for the further development of Semiotics in Informatics. However, through the systematization developed in Chapter 4, it is possible to say that some interpretations of Peirce's work are in contradiction to it, as shown in Chapter 4.

Chapter 4 presents sign relations and categories of signs as lattices, which was done before, and visualizes them as three-dimensional Hasse diagrams. The visualization is intended to facilitate the understanding of their relational nature. A short example may facilitate the readers understanding of its potentiality. Peirce distinguished two types of abstraction, prescisive and hypostatic. Prescisive abstraction is an explanatory concept that describes processes that go from the particular to the general. Hypostatic abstraction describes the inverted process, from the general to the particular. Among his processes of inference he differentiated between induction, deduction, and abduction. Deduction goes from the general to the particular, as usual. Induction goes from the particular to the direction of the general. Induction is not powerful enough to explain the path towards general laws; it only generalizes a finite set of particular cases. Abductions bridges this gap, explaining the processes, for example of theory building or hypothesis making. Laws are tested against the particular, as illustrated in Figure 3.1(a).

This can be easily visualized with the 3D Hasse diagram proposed in Chapter 4, as depicted in Figure 5.2(c) in the case of Peirce's ten categories of ternary signs. The arrows stand for processes of abduction, induction, and deduction that link the traversal of Peirce's ten categories of ternary sign relations, across firstness, secondness, and thirdness.

An area in which the processes of abduction, induction, and deduction could play is Knowledge Representation in Artificial Intelligence. In cognitivist approaches, designers are usually the ones that program the rules into the machine. See Figure 2.3. From the rules, it is possible to deduce what are the steps to be taken to reach a certain goal. Connectionist approaches work by induction, taking particular kinds of samples and "statistically" training them through the artificial neural-network. Abduction may play a role in explaining the differences between the two. The above generalization, is usually restricted to the traditional technological dimension that became Informatics' traditional focus. If extended to the human and interactive dimensions, it is possible to see in a different light early projects such as Engelbart's goal to augment human intellect, and more recent ones such as analyzing usage patterns to guide design, or even the inner workings of search engines. The multidimensional facets of this framework can also inform and facilitate a critical appraisal of other approaches in the cognitive sciences in which language and instruments play a role as mediatory artifacts, such as distributed cognition (Hutchins), language action (Winograd), situated action (Suchman), and theory of activity (Nardi), among others.

Across the ten categories of ternary signs either one arrives at a state of generality, a law, or not. In the refinement of ternary into decadic signs it is possible to differentiate states of signs that tend to a certain generality (dynamic) but that are not yet in that final state (final). See Figure 1.10 in Chapter 1.

Chapter 4 gives important contributions of Informatics to the field of Semiotics, and indirectly to the approaches in Informatics that are exploring it as a reflective scaffold. Indeed, the language in which signs and its categories are described is made clearer with the aid of structures commonly used in Informatics. I am aware that to understand it in its full depth the reader will need to understand both the structures I am using and the concept of sign relations and categories of signs. I hope that in the long term this may not only facilitate an understanding of Peirce's categories, but also the avoidance of common misunderstandings.

Another topic I would like to explore in Peirce's work in relation to Semiotics is how knowledge is transmitted (Methodeutic) and its conditions of truth (Critic). This would give substance to the abstract structures I discussed in Chapter 4, which may at a first sight be overlooked as either a topic in Informatics, or one in Semiotics. As described, but not commented in Chapter 3, two-dimensional diagrams depicted in Figure 3.11 have been proposed to study genres of interfaces. They played an important role in HCI delimiting different genres of interaction such as command languages and direct manipulation. With that, the previously limited horizon of interaction only as programming was surpassed. These models, or classificatory schemata, indeed went beyond the monadic nature of previous ones. There is no need to say that if there is only one class of things, there is no sense in classifying it. Only when different genres of interfaces started to be expressive enough to be noted did researchers start to classify them in order to better understand their relationship. The extensions were structured on distinctions as objective and subjective, expression and content, manipulation and conversation, individual and collective, and semantic distance. It is when the relations between genres of interaction start to be relevant that two-dimensional models are not powerful enough.

Indeed, the addition of a third dimension associated with interaction, with mediation, raises questions about the appropriateness of such schemata to describe phenomena such as learning, working, playing, and others that necessarily happen across time. One of Peirce's achievements was a well thought out framework for ternary semiosis, at least. Therefore, his ten categories could be used as an alternative classificatory scheme to differentiate genres of interaction. I have not explored this issue further, but it is clear for me that any endeavor in Informatics that uses Peirce's semiotics as a scaffold would not do justice to his work if restricted to the level of dyadic semiosis. For example, the use of the second trichotomy (iconic, indexical, and symbolic) as a classificatory scheme is misleading because firstly they are not classes. Secondly, understood in the light of the ten categories they are limited to dyads between the representamen and the object, leaving the interpretant out. A better choice would be to use only the cenopythagorean categories, or the full set of ten categories. People do not do that because these categories are not easily mapped onto traditional genres of interaction. To complicate the matter, some of Peirce's terms such as icons and symbols have meanings in his work that are distinct from their meanings.

Peirce's work was an important scaffold to give structure to this text, but I should stress that the contents of this thesis are not intended to be comprehensive in relation to Peirce's systematic philosophy. However, the thesis does an in-depth study of the general principles that structure Peirce's Semiotics, emphasizing its relational and encompassing character.

This is only at the foundations of his work. If Peirce is right, some fields seem less scientific because they encompass a larger number of difficult problems; because they imply a bigger challenge to reflect and act accordingly. The chasm between Informatics/HCI as a practical science and as a theoretical science is still deep and unexplored, and is exactly where the challenge is. If Informatics indeed *represents* something to society, and is a changing force (action), this chasm or part of it will have to be explored sooner or later.

Part III

Appendices

Additional References

Appendix A

Informatics

Computer Engineering	
COSINE (1967)	Computer Sciences in Electrical Engineering
IEEE Computer Society (1977)	Model Curricula in Computer Science and Engineering
IEEE Computer Society (1983)	The Model Program in Computer Science and Engineering
Mulder and Dalphin (1984)	Computer Science Program Requirements and Accreditation: an Interim Report of the ACM/IEEE Computer Society Joint Task Force
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Denning (1998)	Computer Science and Software Engineering Filing for Divorce
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Appendix B

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Appendix C

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Appendix D

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Appendix F

Curriculum Vitae

Name:	Luiz Ernesto Merkle
Place of birth:	Curitiba, Paraná, Brazil
Year of birth:	1962
Post-secondary education and degrees:	Centro Federal de Educação Tecnológica do Paraná Curitiba, Paraná, Brazil 1982-1989 Engineering Centro Federal de Educação Tecnológica do Paraná Curitiba, Paraná, Brazil 1990-91 M.Sc.
Honours and Awards	CNPq Doctoral Scholarship 1995-1999
Related work experience:	Associate Professor Centro Federal de Educação Tecnológica do Paraná 1989-2001

Related Publications:

Merkle, Luiz E. and Mercer, R.E. Are Interactive media as large as life and half as natural? In: HCI International '97 - 7th International Conference on Human-Computer Interaction, August 24-29 1997, San Francisco, California, USA. *Proceedings of the Seventh International Conference on Human-Computer Interaction.* (HCI-International '97). Eds Michael Smith, Gavriel Salvendy, and Richard J. Koubek. Elsevier. 1997. v.2, pp 55-58, 1997a.

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