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ORIGINAL PAPER

Designing Mobile Systems in Highly Dynamic Scenarios: The WORKPAD Methodology

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Abstract The design of interactive systems to be used in mobile and pervasive scenarios, such as emergency management, requires novel methodologies which combine user-centred design approaches and software engineering approaches tailored for distributed architectures. In this paper, the methodology adopted in a successful research project is presented together with a case study.

Keywords User-centred design · Requirement collection · Interaction design · Emergency scenarios · Mobile systems

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Introduction

The purpose of interaction design is to produce interactive systems or products that are, from a user perspective, easy to use, more effective and more enjoyable (Sharp et al. 2007). These interactive systems or products serve the users to complete their tasks in an interactive manner and in a natural way near to human psychology. The process of designing interactive systems does not involve only the interfaces or the immediate interaction; rather, it relates to the complete environment (e.g. the technology, working environment, stakeholders, goals, etc.) surrounding that system; and this process produces a set of resulting artefacts (e.g. documentation, manuals, tutorial, etc.) along with the working system to make the interaction more effective. It is all about what we say and do as well as what we make. The purpose is not just the simplicity but to develop a working system with functionalities and capabilities with an adequate level of usability (Norman 2008). The

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environment in emergency or disaster management scenarios is very critical for many aspects as a small mistake can put many human lives in danger. So, a formal methodology and well-designed principles, for designing and developing an interactive system for supporting emergency operators, plays a critical role in the success of the resulting system.

The term "emergency management" means the coordinated activities both to prevent disaster happenings and to face them when they take place. Such activities consist of five phases (GIS for Emergency Management 2007): planning, mitigation, preparedness, response and recovery. The European project WORKPAD (http://www.workpad-project.eu/) provides a software and communication infrastructure to support operators in emergency scenarios, by focusing on response and short-term recovery phases of emergency management. When a disaster happens, the response phase is designed to provide emergency assistance for victims. It also aims at stabilising the situation and reducing the probability of secondary damage and at speeding recovery actions. The recovery activities aim at returning the living conditions to normal conditions and they usually include two sets of activities. Short-term recovery activities return vital life-support systems to a minimum operating standard. These two phases, response and short-term recovery, are the most critical amongst all five.

In disaster scenarios, different teams belonging to different organisations need to collaborate in order to reach a common goal. So the collaboration within team members and with other teams operating at the disaster site or sites is very critical as the achievement of the desired goal heavily depends on this collaboration. A system working in such a critical environment that lacks the basic interaction principles can be dangerous as it could increases the level of disaster or can make the efforts ineffective in such scenarios. So, to improve the collaboration between teams working in emergency or disaster scenarios the selection of interactive designing principles and the adopted methodology are very critical.

In the WORKPAD project, twofold (bottom-up and top-down) high-level approaches with various human–computer interaction (HCI) techniques were selected for taking the requirements and to design the system. The top-down approach is used to get information regarding the related works, while the bottom-up approach is used to get requirements from the practical work carried out in the field. We also used the experience knowledge of users and technical persons working in the emergency or disaster scenarios to get more user-centred focus. The work done according to the selected approach is as follow:

Bottom-up approach A concrete case study of emergency management in the Calabria region was conducted. Potential users were intensively involved in this project phase according to the international ISO standard 13407 (Human-Centred Design Processes for Interactive Systems; International Standardisation Organisation: Human-Centred Design Processes For Interactive Systems 1999).

Top-down approach On the one hand, we investigated European legislation, recommendations and initiatives with respect to emergency management, and on the other hand, related European research projects were examined regarding the requirements analysis methods adopted, the concrete outcomes and their validity for the WORKPAD project.

The rest of the paper is structured as follows. Section 2 describes the adopted methodology, the designing principles and the approaches that were used to make the system more interactive and more efficient in emergency or disaster scenarios. Section 3 explains in detail the activities that were conducted during designing and developing the WORKPAD project. Section 4 provides an overview of the WORKPAD architecture, and the user interface of mobile devices of team members working at disaster sites. Section 5 gives a comparison of the work done by other research projects in emergency scenarios.

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The paper concludes with Section 6 by highlighting the use of the methodology in another European project, namely SM4ALL.

The Methodology for Designing the WORKPAD Interactive System

The first step is to adopt a methodology for the elicitation of requirements as a process helps more efficiently to elicitate the requirements. The requirement elicitation process per se is an iterative and interactive process incorporating at least three stages with dedicated outcomes (Wiegers 2006). Figure 1 illustrates the three stages that were slightly adapted from (Wiegers and Wiegers 2000) to represent the activities conducted in WORKPAD. The (Wiegers and Wiegers 2000) differentiates between three types of requirements which are inputs to three individual documents.

- *Business Requirements:* "Why" a project or a new development is necessary? These are the driving forces for a project and are usually easy to collect because they are apparent.
- *User Requirements:* "What" will the users finally be able to do with the system, such as tasks or goals they must be able to perform?
- *Functional (or System) Requirements:* "What" are the developers of the system supposed to build? These are the traditional requirements that specify the functionalities of the intended system on a more fine-grained basis.

Figure 1 shows the dependencies and sequences of the various types of requirement documents ("Vision and Scope Document", "Use Case Document", and "System Design Specification" as they are labelled by Wiegers) that were produced in the WORKPAD project. The dashed horizontal lines denote the borders between the different stages of the requirement elicitation process.

User-Centred Design Approach

In order to devise a successful architecture for the WORKPAD project, we followed the user-centred design (UCD) approach adapted from the international ISO 13407 standard (Human-Centred Design Process

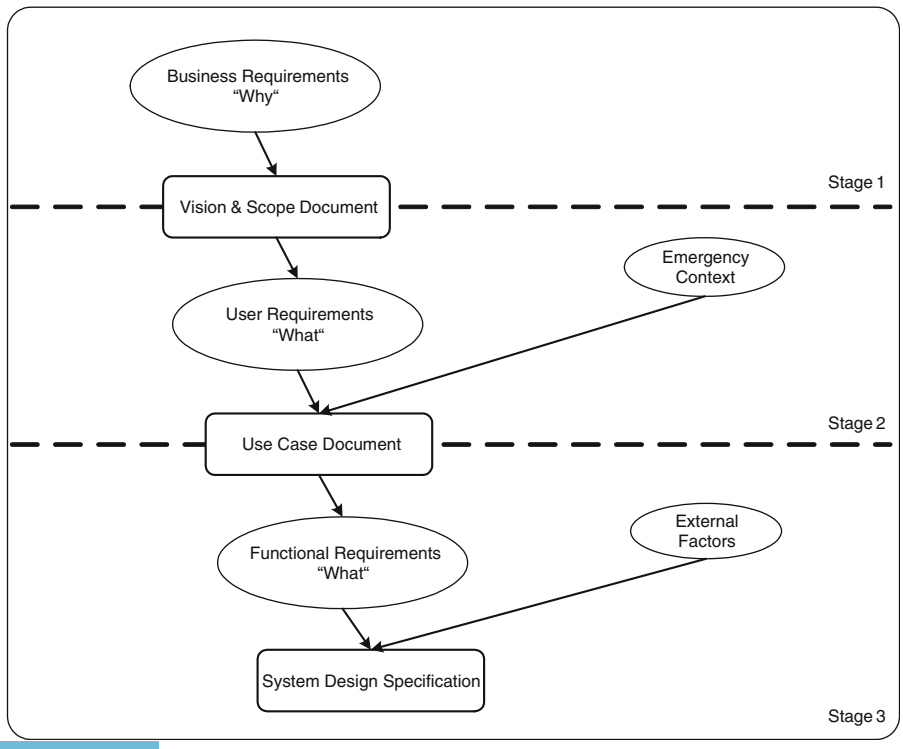

Fig. 1 Requirement engineering process, adopted from (Wiegers 2000)

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for Interactive Systems; International Standardisation Organisation: Human-Centred Design Processes For Interactive Systems 1999). We developed an iterative and incremental approach, as suggested by the ISO 13407. As a consequence, the risk of functionality or usability failure of the WORKPAD prototype was reduced through steady feedbacks with the users accomplished by the iterative approach. They are intended to understand better and better how organisations are arranged during disastrous happenings, how and which information are exchanged among teams and with their respective operational centres. The more the designers are able to go into the "mind" of users, the more the system matches users' needs and is more appreciated by the users. If designers devise systems without continuously taking into account the users' impressions and needs, those systems are going to fail since they will lack the real interaction between system and users. With respect to other methodologies used in previous research projects about emergency management, the main contribution of our work in the WORKPAD project is a careful use of all possible techniques to get feedbacks from the users, such as interviews, scenarios and task analysis (Dix et al. 2003). This requires a continuous contact with real end users, by leading them not only to answer to simple questions but also to think about their suggestions and impressions. The details of the activities that we conducted in the project are in next two subsections.

Requirements Engineering Activities

The activities conducted within the adopted requirement elicitation process are twofold. On the one hand, there is the accomplishment of a case study where the concrete emergency management system of the region of Calabria (Italy) was analysed with respect to the requirements. On the other hand, the activities dealt with examining the related work, such as other past and current European projects with a similar scope—and additionally national and international regulations—with the objective to derive further relevant (mostly high level and rather structural) requirements for the WORKPAD system.

Figure 2 gives an overview of the performed activities, the dependencies and their temporal sequence (from top to bottom in Fig. 2) until even devising a conceptual architecture of the WORKPAD project. The concrete procedure of the conducted activities can be summarised as follows: after the definition of the potential users and user groups of the Calabria, two iterations of interviews and two focused user workshops were conducted, which resulted in a better understanding of the real end-users' problems and their needs (business requirements). Subsequently, with steady user feedbacks realistic scenarios were designed (earthquake and flood). Particular and concrete instances of the rather broadly defined scenarios are called storyboards and were derived from scenarios. The usage of storyboards in the WORKPAD project is

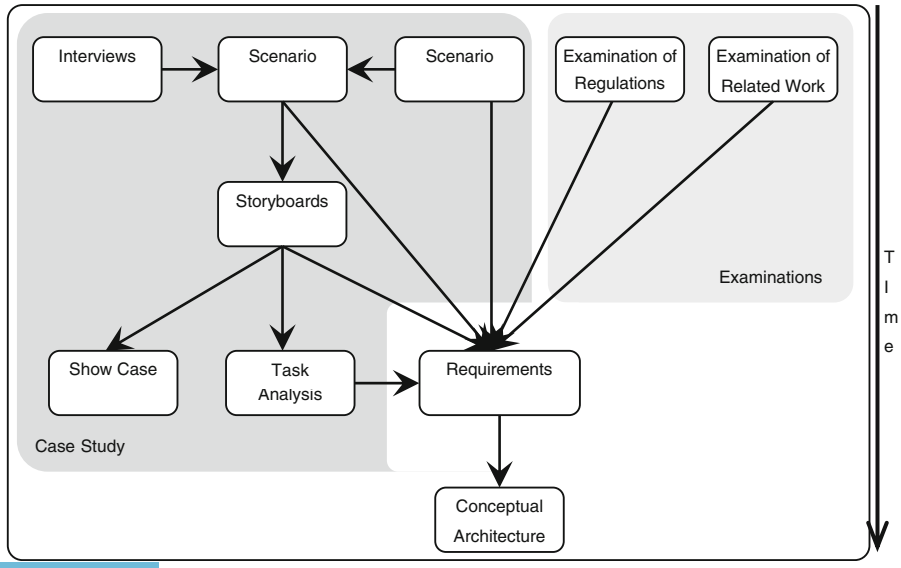

Fig. 2 High-level overview of requirement engineering activities

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threefold: (1) some of them are implemented in the final showcase, (2) they serve as a basis for the task analysis, and (3) specific requirements are directly derived from the storyboards. The task analysis, in turn, also serves as an important input for the requirement collection process.

From the Calabrian case study on the one hand and the theoretical work (examinations) on the other hand, generally applicable requirements for an emergency management system that shall basically be applicable in the whole of Europe were derived. The collected requirements suggested decisions for the design of the conceptual architecture.

System Engineering Methodology by Using UCD Techniques

As described in previous subsections, various UCD activities have been deployed during the analysis of the case study of the Calabria emergency system to capture relevant requirements for the WORKPAD project. Figure 3 gives a more detailed and technical overview of the methodology used only for the practical part of the requirement elicitation process of the WORKPAD project and depicts the several phases and their interrelations. The phases are comprised of the definition of user groups, development of scenarios, task analysis, requirement derivation, use case definition, system requirement analysis, and finally analysis of the required WORKPAD system components.

In WORKPAD, the slightly adapted Scenario-based Requirements Analysis Method (SCRAM (Sutcliffe 2003)) has been used in order to get a realistic understanding of the user's problem context, to derive early requirements that have served as a basis for further UCD activities such as storyboards and hierarchical task analysis (HTA), to design the showcase, and later on to evaluate the WORKPAD approach. The SCRAM used in WORKPAD comprises four sub-phases:

1. Initial requirements capture and domain familiarisation (i.e. business and early user requirements analysis) by interviewing, conducting focus groups and developing scenarios.
2. Design visioning by storyboards and HTAs to provide a more concrete impression of the future functions for users and system engineers by instantiating concrete facets of scenarios.
3. Requirement exploration (i.e. analysing feedbacks from stakeholders to current status of requirements by using scenarios, storyboards, paper-based or real early prototypes, or mock-ups).
4. Prototyping and requirements validation by more functional (horizontal or vertical) software prototypes representing a facet of the intended system to acknowledge requirements, respectively to agree upon necessary refinements or changes.

It starts with personal interviews of the potential users and possible workshops, which gives an opportunity for requirement engineers to better understand the tasks of the users. Interviewing is a guided conversation that involves structured or unstructured discussion between engineers and potential users of the system; this is the most frequently used technique. This phase results in a clear definition of the user groups and in an overview of the current working situation, responsibilities and tasks of the potential users. In the next phase, the engineers and potential users work close on the development of scenarios. Scenario building is an inexpensive and quick method for the collection of requirement and task information, and allows users to create a context for their requirements and tasks. An advantage of this method is that it does not provide any prioritisation of requirements and tasks. We got scenarios through storytelling: users describe situations through stories. Stories are described in a “free-text style”; there is no formalisation, e.g. structure of the processes, required in this phase. The most important result from the scenarios is a deeper understanding of the differences among several users’ groups and their basic work flows performed within the organisations (Denning 2001; Caroll and Rosson 1992). These scenarios serve as basis for the specification of functional requirements and task analysis. Task analysis aims at showing an overall structure of the main user tasks; it includes the overall users’ responsibilities in processes, goals to achieve and tasks that users intend to perform to achieve goals. An approach, known as HTA (Dix et al. 2003), divides high level tasks into their constituent subtasks which, in turn, are further subdivided up to a given level of details. HTA must be independent from the application, the planned system or other techniques used to perform the tasks. So, it is easy to allocate tasks into whichever application, and it enables to easily develop a conceptual model for them. Scenarios and task

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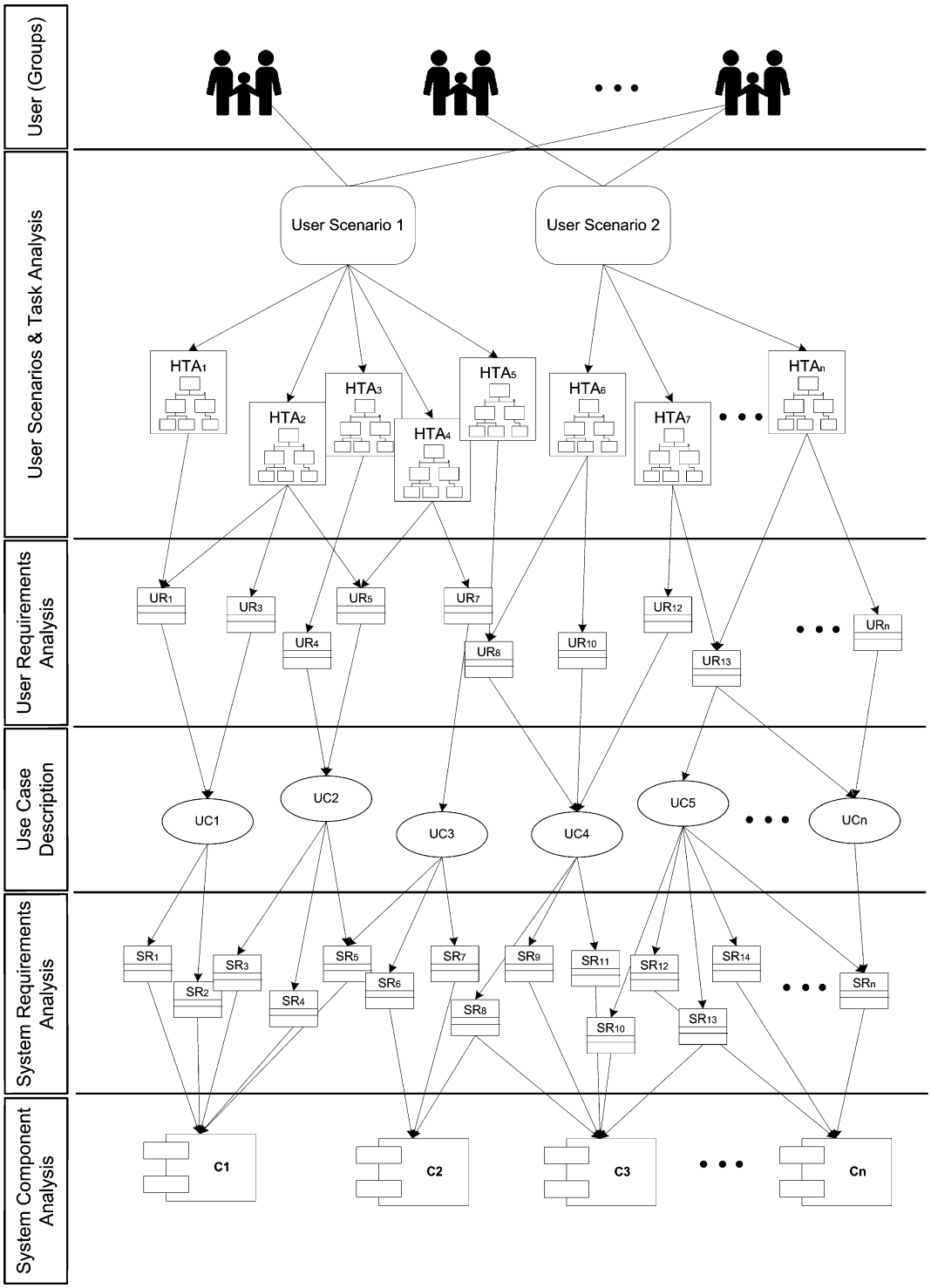

Fig. 3 System engineering methodology

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analysis give the needed input for the user requirement analysis. User requirements allow to define (1) problems each user meets performing her/his tasks, (2) solutions s/he has in mind to solve problems and (3) users' real needs (that is the functionalities that systems, both computer-based and not, have to provide). In general, starting from users requirements, it is possible to distinguish between functional and non-functional system requirements. Functional requirements identify the characteristics and requirements posed on the target applications or systems, whereas non-functional requirements specify global constraints on how the software operates or how the functionalities are exhibited. Once functional requirements (what the system should do) are described in form of use cases, non-functional requirements (performance, reliability, efficiency, security, safety, etc.) can be added.

Case Study

The previous section described the methodology that we adopted for designing and creating an interactive peer-to-peer software infrastructure system supporting collaborative work of human operators in emergency or disaster scenarios. In this section, we describe the work we have done to collect the requirements for the WORKPAD project and to design the system according to the user-centred design approach. After getting all types of requirements described in the previous sections, we designed the WORKPAD architecture, based on a two-level peer-to-peer (P2P), which will be summarised in next section.

On a high-level view, the different phases of the WORKPAD project were organised in three iterations leading to the benefits of having the possibility to refine decisions with respect to, e.g. requirements or system design based on the feedbacks of concrete (preliminary) implementations and pre-evaluations. Consequently, on a "macro basis" the requirement phase iterated three times with a dedicated output of each iteration. As already described, we gathered three kinds of requirements; i.e. business requirements, user requirements and the functional requirements. The following subsections describe the specific work carried out in the WORKPAD project for collecting the requirements through each technique.

Defining Users and Categorisation of User Groups

The first task conducted during the case study of Calabria was to identify the potential users and user groups. In order to understand how Civil Protection works during emergency management, we interviewed some officers and actors which are really involved during emergencies. In collaboration with the Civil Protection Department of Calabria, we identified two typologies of users: back-end and front-end users.

- *Front-end users*: They are all the operators acting directly on the field during emergencies/disasters (ranging from firemen to voluntary associations).
- *Back-end users*: They are all the operators who manage the situation from control rooms, by providing goals/instructions/information to front-end operators. Additionally, the same users can be classified orthogonally with respect to the various organisations potentially involved in emergency situations, such as police, fire brigade, medical board, army, etc. Furthermore, every organisation comprises different roles such as person-in-charge, commander, team leader, team member, radio operator, etc.

Conduction of Initial Interviews (Semi-Structured)

In order to learn users, with their problems and expectations, we developed semi-structured interviews based on the user group definitions. The interview guideline consisted of a general introduction part, the instructions for the moderator and a description of the WORKPAD project; and the second part was represented by the set of questions, divided into three sub-parts: (1) basic data about the interviewee, (2) more general questions and (3) specific questions depending on the user group class that resulted in two variants of questionnaires (one version for the potential front-end users and a second version for the back-end users). Appendix 1 provides the complete questionnaire template that was used while conducting interviews. We used open-ended questions, allowing each interviewee to answer to any question as he/she prefers. Finally, the last part of the questionnaire was a discussion, where the interviewee could reflect again his answers and the moderator had the possibility to ask further questions for clarification.

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We conducted 32 interviews, approximately 45 min length of each, from the officers and generic actors of the most important organisations (e.g. Harbour Office—Coast Guard, Police Headquarter, Civil Protection, State Forest Corp Provincial Headquarters, Italian Red Cross of Calabria region, etc.) involved in emergency management in the Calabria region. We divided these organisations into seven different categories. Figure 4 shows a pie chart in which each slice represents the number of interviews taken in each category. During each interview, the moderator, as the leader of the interview team, was responsible to tell to the interviewee the purpose of the interview and the project and to ask the questions according to the guidelines of the interview template. The answers were recorded by another member of the interview team, who was also responsible to make detailed notes into the specific form. The interviews situations were video-taped by a third (technical) member of the team so that all statements were backed up. The main purpose of the interviews was to identify the users and their activities to manage disasters for which we asked them to imagine a realistic situation that could happen during their work and to describe the tasks to face it.

Constructing Focus Groups, Developing Scenarios and Conducting Targeted Interviews

The scenario-based requirements analysis method is a good way to develop a common understanding of the context, the activities and the problems that an organisation has to face. The scenarios help us to think about the design in detail and notice potential problems before they happen. In the WORKPAD project, we concentrated on two scenarios: earthquake and flood, due to the fact that these are the most relevant ones in our context of study. We designed activity diagrams for both scenarios to describe how the end users would follow in order to face the emergency situation. Each scenario was developed to focus on a different phase of emergency: earthquake scenario covers the response phase, while the flood scenario covers the short-term recovery phase. Despite this difference, at high level the resulting flows of activities are the same in both of them.

Due to the necessity of more detailed data, we conducted 14 further user interviews to refine the proposed storyboards, which at that stage were not perfectly appropriate and detailed enough. These interviews were much more targeted: seven for the earthquake and seven for the flood scenario with specific questions. The result of these interviews served as input for the establishment of ten, more realistic storyboards (five for each scenario) and the subsequent task analysis.

Analysing the Organisational Workflow during Emergencies through Storyboards and Hierarchical Task Analysis

The actual work, which the organisations perform, depends strongly on the disaster characteristics. In order to go deeply into "the mind" of rescue operators, we asked them to illustrate their own personal experiences in past-occurred disasters. These are called storyboards, and describe a specific

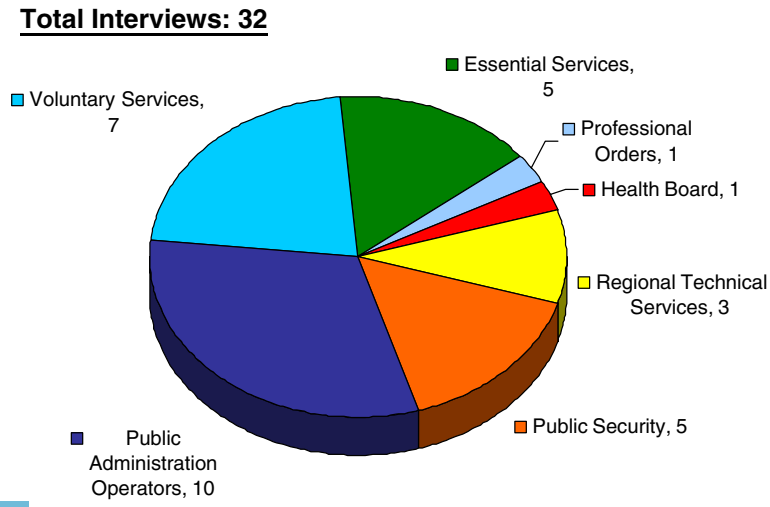

Fig. 4 Number of interviews in each category

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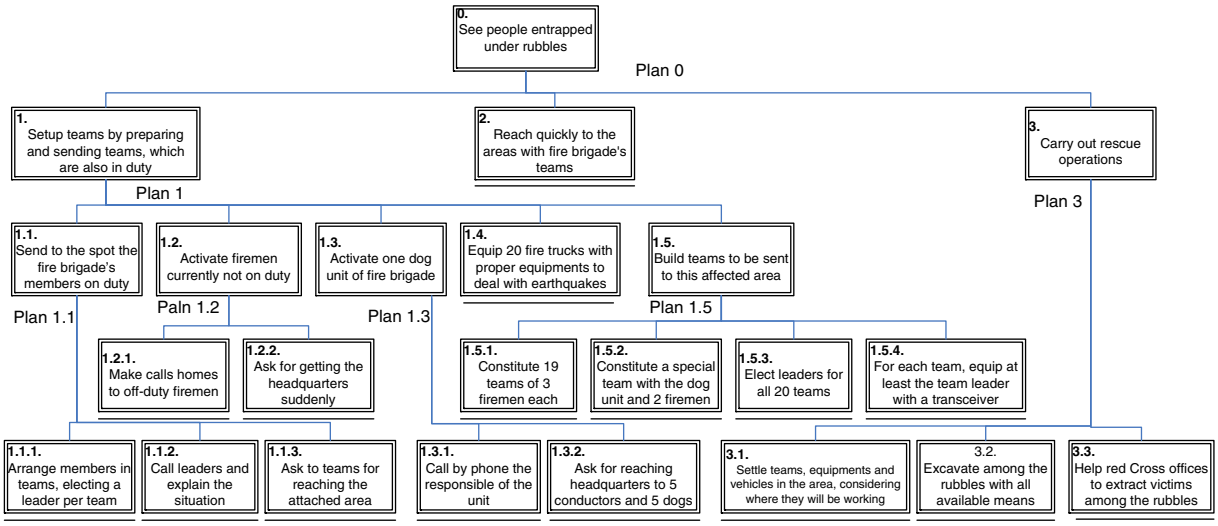
emergency situation to be faced, taking into consideration some relevant conditions and furnishing a goal to reach. The storyboards were presented in a structured way comprising the following information: actor(s), relevant emergency phase, initial state, relevant pre-conditions, final state, main goal, duration, and dependencies.

Using these storyboards, we conducted a task break-down analysis through classical HTA technique (Dix et al. 2003). The task analysis observes user behaviour and focuses only on the strategy as a sequence of steps in order to reach the goal. We stopped the HTA at the lowest level that allows a structured plan to be executed. Figure 5 shows the decomposition of the task "Rescue Entrapped People" (cfr. HTA) in a storyboard about the Fire Brigade's intervention after the collapse of two buildings: the purpose is to save people entrapped into the rabbles.

Requirements Collection through Top-down Approach

In parallel with collecting requirements through the bottom-up approach, more general requirements were identified and analysed by examining several national and international regulation and legislations and additionally investigating related research projects. According to the legislative framework for European emergency management, the WORKPAD system will support response and short-term recovery activities. This means that the focus is on the phase shortly after the disaster has happened and the phase following the response phase. Basically, in most European countries, the emergency management structures are highly similar and always organised as a hierarchy of several levels. This hierarchical organisation needs to be supported by the WORKPAD system in order to be adopted in several countries. The information of the emergency management structures that were examined is based on the Vade mecum of Civil Protection in the European Union (European Council: Establishing a Community Mechanism to Facilitate Reinforced Cooperation in Civil Protection Assistance Interventions (2001/792/EC, Euratom) 2001) and the International Civil Defence Directory (International Civil Defense Directory 2007). Concerning the analysed requirements of other projects, we noticed that many of them are too high-level. So, we took into account mainly those few which are obtained and valid for the WORKPAD system.



Plan 0: Do 1 and then. Upond arriving of the fire trucks, do 3.
Plan 1: Do 1.1; then do 1.2, 1.3, 1.4 contemporaneously. Afterwards do 1.5.
Plan 1.1: Do 1.1.1, then 1.1.2, and finally 1.1.3.
Plan 1.2: Repeat 1.2.1 followed by 1.2.2 while all the available functionaries are alerted to reach headquarters.
Plan 1.3: Do 1.3.1, then 1.3.2.
Plan 1.5: Do 1.5.1, 1.5.2 in an orbitrary order. Then do 1.5.3, 1.5.4 in orbitrary order.
Plan 3: Do 3.1; then do 3.2, 3.3 contemporaneously.

Fig. 5 Task analysis and execution plan

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Analysing and Structuring User Requirements

As described earlier, the requirements were collected with a twofold approach and categorised according to forms categories: *general*, *communication*, *back-end* and *front-end*. Furthermore, we presented the requirements in a structured way to provide additional information for designing, implementing, testing and for requirements tracing issues by specifying: unique identifier, title, an optional description, classification (according to general, communication, back-end or front-end), significance for emergency management in general, priority for the implementation, relevancy (for either earthquake or flood scenario or showcase), source, dependency to other requirements and the evaluation method.

Application of Use Case Methodology for Observing Interactions Between Users and the System

In the WORKPAD requirement engineering methodology, we also adopted the use-case-oriented analysis of requirements. Use-case-oriented system analysis was introduced in (Jacobson and Rumbaugh 1999). A use case defines an interaction or a sequence of interactions of an actor with the intended system. As depicted in Fig. 3 user requirements serve as input for the use cases and system requirements are the outputs. Use cases in WORKPAD are described through UML use case diagrams and a tabular notation.

Figure 6 shows the overall use case diagram of the WORKPAD system. The left-hand side of Fig. 6 shows those actors, team members and team leader, who interact directly with the user interface of the WORKPAD system, while those actors who interact with the back end of the WORKPAD system are on the right hand side. In the middle of the diagram the middleware components of the WORKPAD system, such as the PMS, CMMF and the mobile ad hoc network (MANET) part, are shown.

Conduction of System Requirements Analysis

According to (Sodhi and Sodhi 2003), in the WORKPAD project system requirements were derived from various sources, usually the users of the system; insights from similar initiatives (i.e. related work); domain experts or system engineers (i.e. technicians). The first two were covered during the development of the bottom-up and the top-down approaches. Furthermore, the third important source (domain experts or system engineers) is represented by the technical partners in the WORKPAD consortium. To exploit the expertise and experience of the relevant people, suitable use cases were designed. The overall set of the resulting system requirements were clustered according to the functional entities of the intended WORKPAD system.

Generation of System Component Model

The system component analysis, as the last stage of the adopted methodology, is the interface to the concrete design and implementation tasks and work packages in the WORKPAD. Based on the collected requirements, on the insights gathered through several discussions, especially with the users and experiences of the partners within the WORKPAD consortium, the initial analysis of the core components of the WORKPAD emergency management system was conducted. The logical and high-level structure of having a front-end, back-end and a front-end to back-end link was obvious and, hence, quickly derived. To provide the required flexibility in a highly dynamic environment (i.e. emergency situations), we decided to base the WORKPAD system on a peer-to-peer architecture. Both the front-end and the back-end components were integrated accordingly. Furthermore, each component was structured as a layered architecture in order to separate the different aspects (such as network issues, middleware and applications) and to encapsulate necessary functionalities in each layer providing suitable interfaces to exploit exchangeability, extensibility and reusability.

Architectural Design Decisions based on the Requirements Collection

The high-level design of the WORKPAD conceptual architecture was established taking the results of the requirement elicitation process as the basis. Each design decision was made based on one or more requirements. In addition, several design decisions cannot be directly traced back to one concrete requirement but are the result of several discussions and experiences of the WORKPAD consortium (e.g. the P2P-based two-layered design of the WORKPAD system, i.e. front-end and back-end). To structure the conceptual architecture, several components were grouped together, and, where appropriate, layered structures were elaborated.

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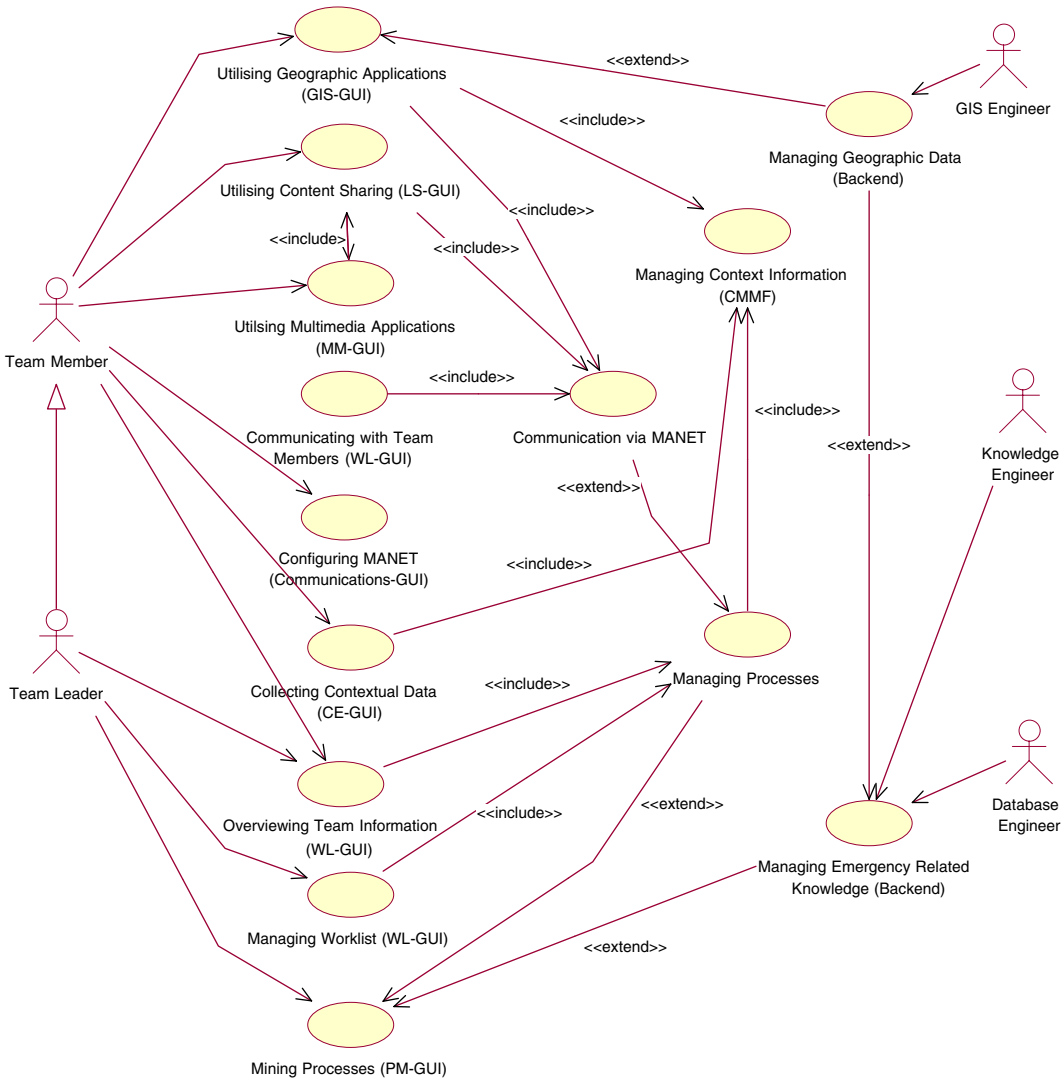

Fig. 6 Overall use case diagram of WORKPAD

The WORKPAD User Interface

In this section, we first describe the architecture of WORKPAD and then we demonstrate the user interface of the mobile devices that the mobile teams will carrying while working in emergency or disaster sites.

The WORKPAD Architecture

Figure 7 shows the WORKPAD architecture. Several teams comprise the system's front-end: team members belong to the same organisation (e.g. police or the fire departments) and carry mobile devices (such as PDAs and smart phones). They establish a MANET for coordination and intra-teams communication. In MANET, nodes can communicate with each other without an underlying infrastructure. All nodes maintain routing tables so they can identify useful paths for forwarding data packets. The lack of fixed infrastructure makes this kind of network suitable in emergency management or disaster scenarios, in which users must quickly deploy a network but access points are not guaranteed.

The WORKPAD back-end is a P2P overlay network that includes the operating organisation's back-office

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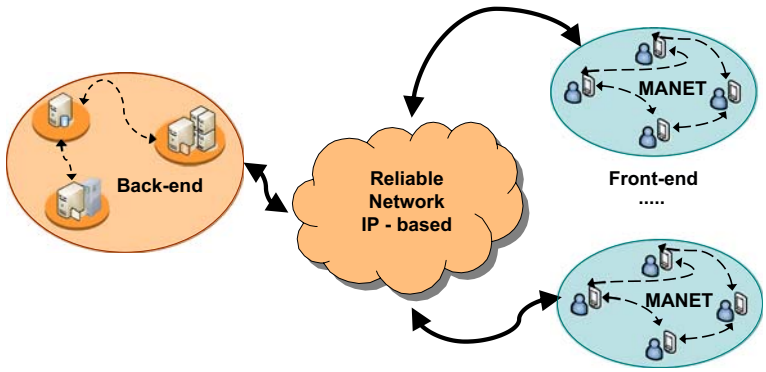

Fig. 7 The WORKPAD architecture

systems (such as services and databases). By entering the WORKPAD network, back-end peers can easily integrate their data, content and knowledge. Front-end operators access the back-end network through their back-office systems. There, they can get or set the information that is relevant to their situation or planned action. Because of the integration layer, such information is not necessarily contained in a single system but is potentially spread over the network and is delivered, collected and reconciled on demand.

Front-End Architecture Figure 8 shows the conceptual architecture of the WORKPAD front-end. The front-end consists of a communication management layer, a middleware layer and the user layer. Each layer has several components. We have not deployed all the components shown in the architecture in every front-end device. Instead, we customise their development, depending on the device's capabilities and the role of the team member controlling the device. The communication management layer includes two modules: The *MANET communication module* that implements MANET multi-hop communication and a front-end/back-end gateway to handle connections with the back end. The *Adaptive Process Management System* (APMS) is the core element of the front-end middleware. It adaptively controls emergency-management processes based on contextual information retrieved by the *Context Monitoring and Management*. This context information is associated with devices, networks, team members, activities, and so on. The middleware layer at generic nodes is simple, consisting only of the specific modules whose purpose is to interact with the team leader's counterparts. The user layer includes a *Worklist Handler* that keeps the tasks assigned to that particular user, and this handler knows which service or application is required for execution of a particular task. The *Context Editor* component allows users to enter additional contextual information that the front-end middleware could not capture. The user layer also includes the *Lightweight Storage* module for data and knowledge storing (either local or distributed).

Back-End Architecture WORKPAD front-end networks are connected to specific back-end systems, and a Web services platform allows them to exchange and integrate data. This platform is designed as a P2P network, in which each system (peer) can act as a data provider, consumer and integrator. By plugging into WORKPAD's back-end network, a back-office system qualifies as a WORKPAD back-end peer. This peer exports its ontology (i.e. a schema reflecting its conceptual model); allows a rapid integration of various data sources, both internal and external (including other peers), through mapping from available sources to a general ontology and can answer conjunctive queries expressed in the alphabet of ontology terms. Front-end services or other back-end systems can issues these queries.

The User Interface

The teams working in disaster or emergency situations will use smart devices in very dynamic and mobile scenarios over a network partially unreliable. Therefore, some challenging issues emerge, which we divided in two categories. The first category concerns grasping the users' mental attentions onto the system as little as possible because pervasive processes are really challenging and stressing for them. The latter category of issues is merely technological and deals with reducing the resource consumptions.

The human beings receive continuously a huge quantity of stimuli from the environment. In (Sternberg

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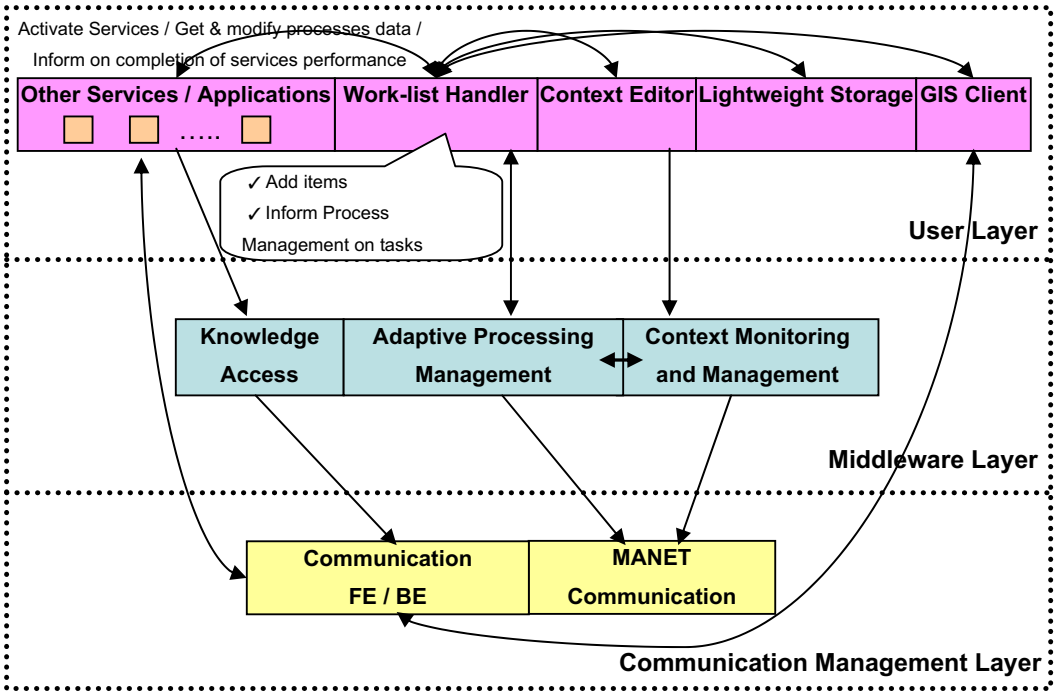
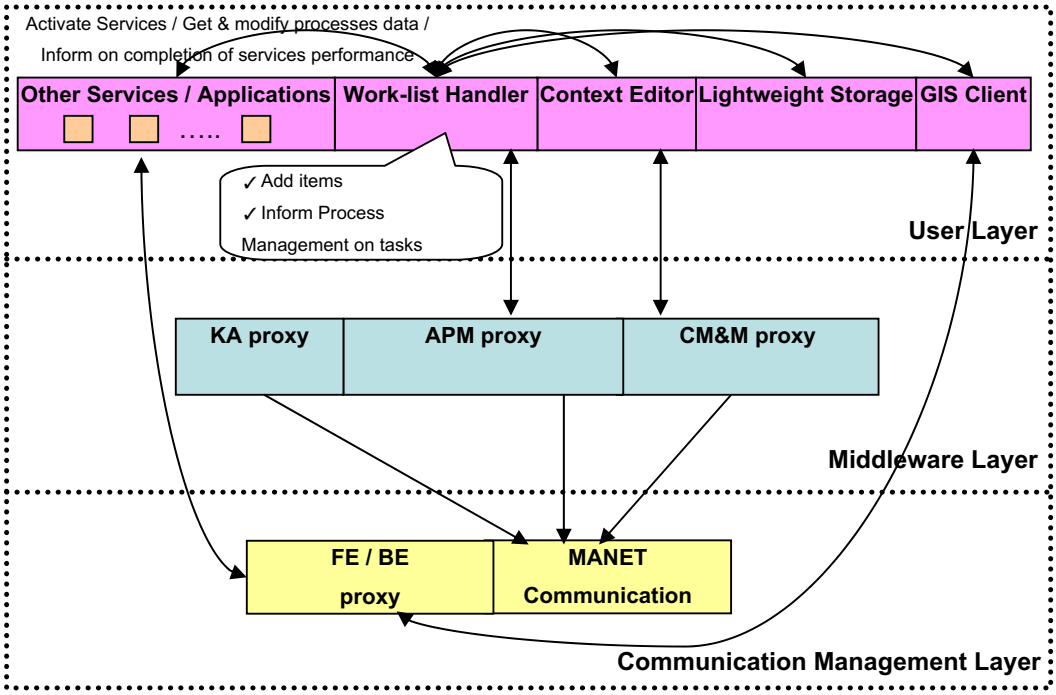


(a) Coordinator Peer



(a) Generic Peer

Fig. 8 Overview of components of the WORKPAD front-end

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2002), *attention* is defined as the totality of information cognitively manipulated by a person. The attention allows human beings to consider stimuli in a judicious way, prioritising them and taking into account only the most important ones. This judiciousness is used to increase the probability of a rapid and accurate answer. Activities in critical and emergency scenarios are highly-stressing situations for the users, who generally give more priority on the physical stimuli concerning the activities to execute than on those coming from software applications. Therefore, when designing client interfaces for mobile, pervasive and critical scenarios, it is important that task handler interface should attract the user attention only when it is strictly required. For instance, we have made a significant use of pop-ups and sonorous alarms to achieve these results. An aspect worthy to consider is accessibility and ergonomics when using PDAs in critical emergency scenarios. Indeed, we have taken into account the fact that these devices may be used in extreme conditions. So, particular precautions must be taken when designing the user interface. In particular, the choice of colours should be effective and easy-to-read; they should be highly contrasting in order to be clearly visible in particular light conditions (e.g. in night missions). Moreover, the interaction with the interface takes mostly place through fingers, instead of the stylus. Therefore, the user interface elements should be sized and spaced out in order to avoid the users to press on wrong elements because they are close to those that the users were willing to push.

On the technical point of view, when devising the system we kept in mind to reduce as much as possible the use of three kinds of resources: the computational power, the bandwidth and the battery, that are quite limited for smart devices.

Figures 9 and 10 show few screen shots of the Task Handler of WORKPAD user interface of the front-end application. The idea of the user interaction is following: Every task is associated with a set of conditions to hold in order that it can be assigned; conditions are defined on control and data flow (e.g. a previous task has to be finished, a variable needs to get assigned to a specific range of values, etc.). Of course, not every member is able to execute every task. Every task needs to be assigned to a certain member that provides certain capabilities. We model that by binding each task to a set of capabilities; in addition, every member declares to furnish certain capabilities. Considering the control and data flow, the APMS assigns every task to a certain member providing all required capabilities (Battista et al. 2008). Every member device (including the leader) deploys a Task Handler, which allows to join the team and to specify the capability the members can provide. Then, it stays waiting for notification of task assignments (Figs. 9b and 10a). The next task to work on is then visualised on the screen; when the member is ready to start it, she picks it, and possibly, appropriate applications are started to support the task execution.

Related Work

In recent years, many projects and initiatives, especially in Europe, have investigated issues related to the ones considered by the WORKPAD project. Few examples of these research projects are AMIRA, LIAISON, OASIS, ORCHESTRA and WIN. One of the main objectives of these research projects is the contribution to open platforms, integrated systems, and components for improved risk management, civil security applications and environmental management. Furthermore, they want to foster a European info-structure and service platform that will facilitate the use of interoperable components and sub-systems. In this section, first, we will describe very briefly the methodology each of the above adopted, and then at the end, we will compare with ours.

AMIRA[1] project provides a set of back-end reusable components using search, reasoning, speech dialogue technology and collaborative working techniques that can be used to create a variety of applications for mobile workers operating in safety or business critical situation. Its area of application is emergency fire services and vehicles roadside assistance. The methodology they adopted can be divided into three analysis levels: knowledge-based interrogation and analysis level in which existing knowledge bases and documents are analysed to get an overview of the current state of working and the end-users skills; interviews and questionnaires level for acquisition of the knowledge about end-users domain and to review

[1] http://www.amira.no/

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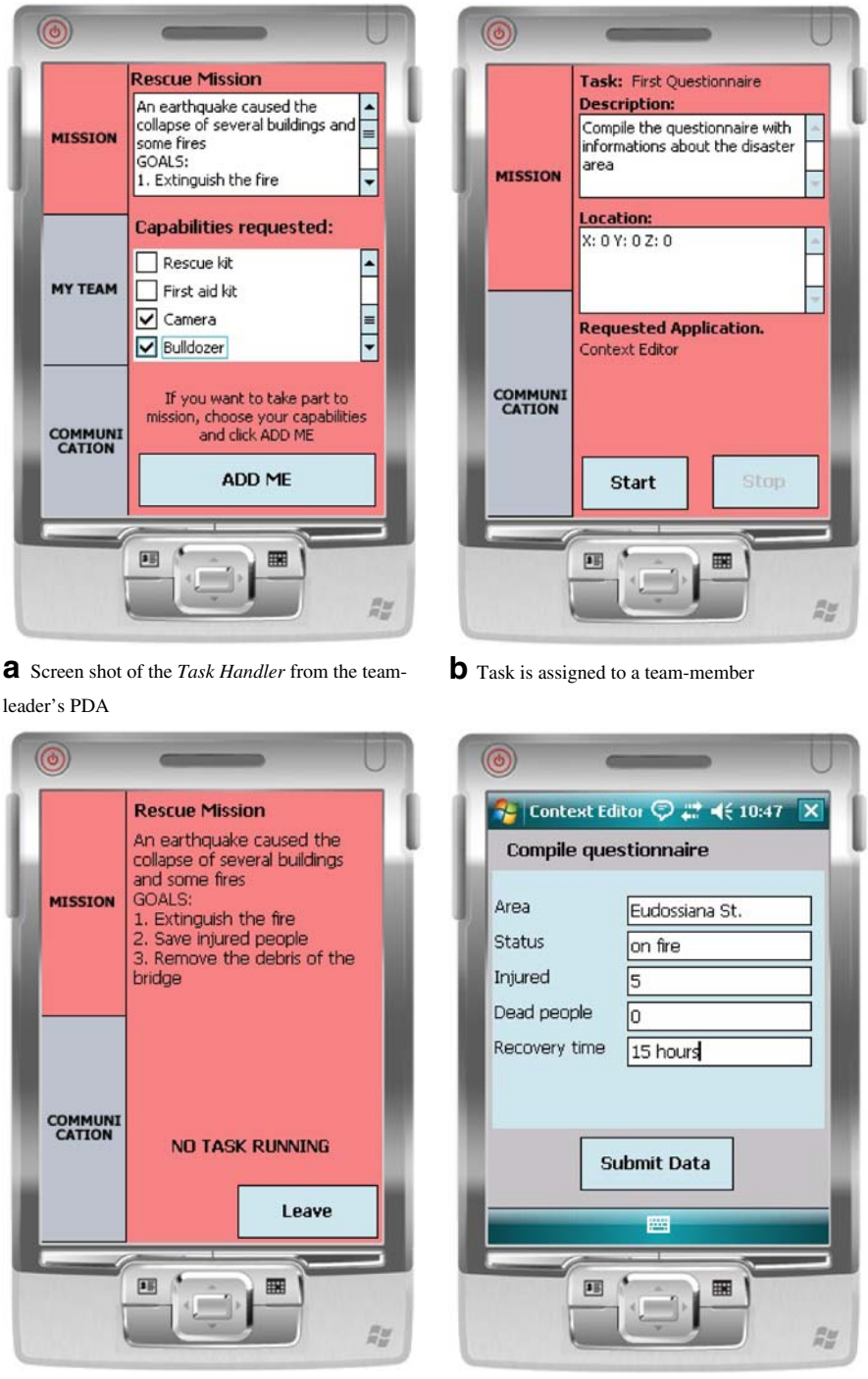

a Screen shot of the *Task Handler* from the team-leader's PDA

b Task is assigned to a team-member

c Details of the critical situation from another member's PDA

d *Context Editor* of the *Task Handler* that is meant to fill in a certain questionnaire for the assessment

Fig. 9 Some screen shots *of Task Handler*. **a** Screen shot of the *Task Handler* from the team-leader's PDA. **b** Task is assigned to a team-member. **c** Details of the critical situation from another member's PDA. **d** *Context Editor* of the *Task Handler* that is meant to fill in a certain questionnaire for the assessment

of the first level result and the requirement assessment level to present the conclusion drawn from the previous level. At this level, working processes are identified and become the basis for elaborating user scenarios. Moreover, user needs are elicited, formulated, defined and evaluated. This analysis of user needs covers the development of user requirements and the use cases.

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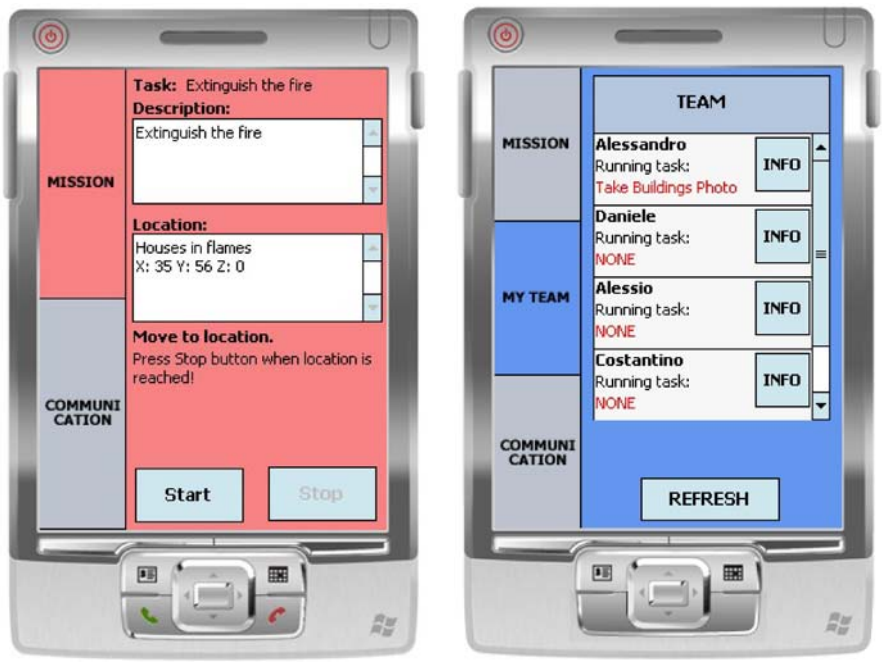

a Another task is assigned to a team-member

b The status of all team members on team-leader's device

Fig. 10 Some screen shots of *Task Handler* (continued). **a** Another task is assigned to a team-member. **b** The status of all team members on team-leader's device

LIAISON[2] project provides location-based services for a wide range of mobile workers by combining existing standards and techniques as well as the newest telecommunication techniques. They adopted two methodological concepts: the SPIN approach that is based on customer-oriented selling and consists of four steps: Situation, Problem, Implication and Need; and then through use-case methodology by using the information taken from interviews in SPIN approach.

OASIS[3] project defines and provides an open, modular and generic disaster and emergency management system. In this project, a two-stage methodology was adopted. In the first stage, structured interviews were taken with different emergency responder organisations along taking requirements from the public available material and other relevant projects. While during the second stage, focus was on taking interviews to collect information from users working in other countries. At the end of both stages, the user requirements came out after combining the result of first and second stage.

ORCHESTRA[4] provides an open service-oriented software architecture to improve the interoperability among actors involved in disaster and emergency management operations. They adopted a methodology so called "line of arguments" for defining the requirements. The process starts with defining the user types and the respective roles; then connecting these user roles with fundamental challenges relevant to the system; then creation of key system requirements from these fundamental challenges and finally, the creation of architectural principles based on the previous key system requirements.

The objective of the WIN[5] project is to design an information architecture ("info-structure") based on the state-of-the-art information technologies, protocols and standards while providing the interoperability with existing risk management services. A two-stage methodology for the requirements analysis was used. During the first stage, the requirements collection process was perform by the thematic actors of the project; while in the second stage, additional requirements, resulting

[2] http://liaison.newapplication.it/liaison/

[3] http://www.oasis-fp6.org/

[4] http://www.eu-orchestra.org/

[5] http://www.win-eu.org/

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from the French emergency management lessons learned on daily work, were integrated. During this process, a user-oriented classification approach has been adopted to represent a good model of the scenarios.

By analysis of the methodologies used in above projects, apparently, there comes out the result that all above-investigated projects adopted nearly similar methods to collect requirements: end-user interviews in addition to reviews of previous related works (requirements coming from former projects and EU recommendation papers). Table 1 confronts the analysed projects and the deployed requirements capturing methods. It shows that LIAISON conducted no review of the former projects or related works. The other projects all involved user interviews, and in OASIS and WIN there also a second iteration of interviews was conducted. The analysis also shows that a second iteration of interviews get benefits. According to our examinations, the OASIS project is really the most close to the WORKPAD project among the related projects in the context and the objectives wise. The table does not has information about ORCHESTRA project, as the project description provides the going-to-use approach but does not give any details about user involvement.

In WORKPAD project, besides the theoretical examination of the related work, we also worked together as closely as possible with real-end users in the practical field (the case study of emergency management in the region of Calabria). We designed the requirements analysis with respect to chosen show-case accordingly. Moreover, our methodology not only used the interviews as the only human-computer interaction technique, but it is deeply based on the user-centred design approach adopted from international ISO 13407 standard (International Standardisation Organisation: Human-Centred Design Processes For Interactive Systems 1999) so to deploy iteratively other HCI techniques such as scenarios, focus group meetings, storyboards, and task analysis. This iteratively and incremental usages of UCD approach by involving real-end users in every phase of designing and development is the main difference between WORKPAD methodology and the methodologies adopted in above-related projects.

Conclusion and Future Work

To produce interactive systems or products, a balance is needed between different components of the environment surrounding the system and the interaction between this environment and the system. Managing such a balance largely depends on the methodology and design principles chosen while designing and developing such interactive systems. A well-focused methodology and interactive design principles, with focus on the target environment within constraint limitations, lead to the success of the resulting system or product. In this paper, we present the methodology and the design principles that we adopted while designing and developing the European WORKPAD project, which provides an adaptive P2P software and communication infrastructure to support human operators working in emergency or disaster scenarios. The WORKPAD project focuses on the most critical phases (response and short-term recovery) of disasters and provides an interactive system for mobile human-teams working in such scenarios. To cope the challenges in this critical environment, we adopted a twofold methodology (bottom-up and top-down) with focus on UCD principles, so to use many techniques to get requirements and feedbacks from real-end users, working in these scenarios, by leading them not only to answer simple questions but also to think about their suggestions and impressions. This approach of continuously involving real-end users for getting requirements and

Table 1 Comparison of the user methodology of related EU research projects

	Review of former projects	Review of publicly available documents	Interviews	Second interview iteration
AMIRA	Yes	Yes	Yes	No
LIAISON	No	No	Yes	No
OASIS	Yes	Yes	Yes	Yes
WIN	Yes	No	Yes	Yes

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designing the system is the main difference between the WORKPAD project and the previous research projects for emergency or disaster scenarios.

Currently, we are working on another European project SM4ALL (Smart Homes for All) that aims of investigating an innovative middleware platform for inter-working of smart-embedded services in immersive and person-centric environments, through the use of composability and semantic techniques for dynamic service reconfiguration. We are successfully applying here the same methodology (the twofold one with focus on UCD principles) after a further refinement.

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Appendix 1

Interview Template

The moderator asks potential users the following questions:

Basic Data

Date:

Name of the interviewed person:

Organisation:

Position in the organisation

Moderator:

Present Persons:

Question 1: What are your main responsibilities within this organisation?

Question 2: In what kind of emergencies is your organisation involved?

Question 3: What is your role during an emergency? In which phase of an emergency are you involved?

Question 4: Do you know the statistical frequency according to which an emergency happens in your territory?

At this point (it depends on the user), the interview is divided in two trunks: the first concerns front-end users and the second concerns back-end users. The main idea is to immerse the user in the context of an emergency. It means that we have to investigate the steps that the user performs when preparing himself to face the emergency (when he/she gets a call related to an emergency), until the moment in which he/she has to act really. In this way, we create an "implicit scenario" for the user (he/she believes to be in an emergency situation), and he can answer in the way he wants to.

Front End User

Shortly after the emergency has happened

Question 5a: Which steps do you perform shortly after the emergency has happened?

Question 6a: What kind of information (related to the emergency) do you get from the control centre?

Question 7a: How long is the front-end team actively involved in this phase of the emergency (average)?

Question 8a: What kind of information do you exchange with other members of the team during the transport to the place where the emergency has happened?

During the emergency

Question 9a: Describe the composition of the team and the various roles of the team members allocated to them during the emergency.

Question 10a: What kind of technical devices do you currently use in emergencies?

Question 11a: How do you communicate with the other team members and the back-end centre?

Does your team use a separate communication channel?

Question 12a: What kind of technology do you currently use in/after emergency situations?

Question 13a: What kind of information (and in which form) do you exchange with the team leader?

Question 14a: What kind of information (and in which form) do you exchange with the back-end centre?

Question 15a: Do you co-operate with members of other organisations? (For example police, etc.)?

Do you exchange information and/or data?

Do you share a common technology?

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Back End User

Shortly after the emergency has happened

Question 5b: Which steps do you perform shortly after the emergency has happened?

Question 6b: How much time are the back-end team actively involved in this phase of the emergency (average)?

Question 7b: What kind of information do you send to front-end operators, who have to prepare them to face the emergency?

Question 8b: In what way do you obtain such information and in which format?

Question 9b: Please, describe the structure of your organisation and the various roles assigned to the team members in this phase of the emergency?

During the emergency

Question 10b: What kind of technical devices do you use for the communication with the front-end operators?

Question 11b: What kind of communication technology do you use?

Does your organisation use a separate communication channel?

Question 12b: Does the communication take place with a particular team member(s) or can you communicate arbitrarily with everybody (how strict are the hierarchical and the communication structures defined within your organisation)?

Question 13b: What kind of information do you send to the front-end users?

Question 14b: What kind of information do you receive from the front-end users?

Question 15b: Do you share technology and data with other organisations?

Which kind of data/technology?

In which way does this exchange of information take place?

The last questions are the same for every user.

Question 16: Do you currently use Geographic Information Systems (GIS)?

If yes, which software and data do you use?

Question 17: Do you think that the devices and technologies used to face the emergency are conform to the purpose for which they are used?

Question 18: What do you think would be a big improvement concerning the technology part?

What kind of improvement would you propose?

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