Asymmetric and Adaptive Conference Systems for Enabling Computer-Supported Mobile Activities

by

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Dissertation

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Preface

This work was conducted at the Darmstadt University of Technology, essentially between 1998 and 2002. Before and during this period, I was working at the INI-GraphicsNet, Darmstadt, first in the Zentrum für Graphische Datenverarbeitung e.V., and then later at the Fraunhofer-Institut für Graphische Datenverarbeitung (IGD), as a researcher. This thesis addresses the investigations and results achieved during my work at these organizations.

My initial development projects in the area of mobile computing were very challenging due to the immense constraints posed by the then incipient hardware and wireless network infrastructures, and similarly overwhelming due to the desire to employ those fascinating appliances by all means possible. The endeavour to keep the respective application systems in a course of continuous improvement (i.e., with richer media presentation and "interactiveness"), and at the same astonishing pace as the technological evolutions, was both demanding and rewarding; however, it turned out to be a questionable procedure. After several prototype demonstrations and observations, there came a turning point, following the acknowledgement that, for application cases involving user mobility, the supporting tool is appraised significantly on the basis of its adequacy for the usage conditions and its flexibility to adapt to changing requirements and to any platform specification or resource availability.

The circumstances of a mobile use (e.g., outdoor, on the move, in confined places) require new approaches in application system development and create a high demand for specialized, task-oriented system features. Any service being offered has to be able to account for, adjust itself, and be responsive to the increasing and unpredictable diversity of prospective users and their usage environments. The achievement of this attribute is even more challenging when the service should be a basis for a digitally mediated human-to-human communication process involving all kinds of diversity between the individual partners and technical arrangements.

In this thesis work, proposals and innovative solutions to these challenges have been investigated and implemented, and are presented in this report. Some contributions of this work are: an adaptive conference system for heterogeneous environments, tools to assess, distribute, and respond to User Profiles at both the individual and collective level; adaptive, flexible individual interaction modes and media that are nevertheless consistent for a collaborative work; and mechanisms for remote awareness (of constraints) for structuring interaction. However, above any technological advances, the major research challenge was concerned with the human factor and the achievement of an effective integration of a supporting tool in their daily activities and lives.

Stylistic Conventions

In this work, the central character is the user and, to some extent, the system designer, as well. When referring to either one of them, the singular pronoun 'he' is used as a generic term. This should not be taken to imply anything about the composition of any population; whenever the masculine form (e.g., "he") is used, the feminine form (e.g., "she") is meant, as well. For easy reading, all composed forms ("his/her", "him/her", "himself/herself") will not be used.

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I am most grateful to all those colleagues and friends who, during my time at the IGD and in Germany, have provided me with their much-enjoyed companionship and an intense belief in humankind above all social and working challenges.

The solemnity of the moment compels me to formally express my profound gratitude to my beloved family and dearest friends for their friendship, teaching, and motivation, not only in pursuing my career, but also throughout my life.

To my beloved parents

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Chapter 1: Introduction

The immaturity of computer services in terms of their awareness and responsiveness to user mobility, as well as the constraints of the hardware and network platform for mobile practices, constitute the foundations for the research and consequent new proposals for the development of computer services tailored to the mobile scenario.

In this chapter, the objectives of this research are laid out and its organisation is described. In addition, a literature review is performed to present the background and position of this research.

1.1 A New Approach to the Development of Computer Services

People acquire new habits and methods of work in part from the material progress they experience. Nevertheless, this progress derives from their own faculties and desires to improve the quality of their life and to optimise working practices.

As an illustrative fact, the technological achievements of the recent cellular telephony have widely spread a ubiquitous form of inter-personal communication, very much in tune with the human pursuit of being free to relocate and yet uphold a communication channel to the people of one's choosing. These fulfilled aims and progress are both commonplace nowadays in most of the urban areas of the planet. Moreover, they have substantially contributed to promoting the interest in radio communication and, thus, to giving an upward impulse to wireless data networking and the already prosperous communion of computing with communication technologies.

Similar achievements, in respect to a supported mobility, concern developments for bringing computational resources into nomadic or roaming working practices. Here, these developments refer to the miniaturisation of computers, which allows the processing units and services of interest to 'be taken' out of the office and to accompany the users at any place in any eventuality. The merging of further achievements in both areas–remote access through wireless networks and portable computers–have been key ingredients for enabling an unrestricted usage of computational resources virtually anywhere, at anytime. This combination of technologies has been termed "Mobile Computing".

With the growing establishment and reliability of the technologies involved, Mobile Computing has also penetrated into segments of technical work practices of a mobile nature. The demand is mainly among professionals, who for their duties, need to be in transit, in remote places, or simply away from office facilities. Besides, they still need a mobile apparatus that provides them with access to their usual applications, database, and multimedia services, or to supporting systems dedicated to their mobile tasks.

Nevertheless, compact devices will certainly always be less 'computationally capable' than their static and contemporaneous counterparts; also, restraining conditions of the users' physical environment and parallel actions frequently impair their usability. In addition, networking in the form of wireless links is still far away from offering the range of services, reliability, and performance of the wired networks. Therefore, the expected support remains doubtful.

Despite these evidences being known, it can be observed that most of the existing commercial application systems seem to be either unaware of or do not directly address the idiosyncrasies of a mobile platform and the circumstances of a mobile usage. The author acknowledges that the hindrances mentioned are not adequately considered or are even neglected in the design of the systems; thus, affecting the efficiency and effectiveness of the respective services and, so, the users' accomplishment of their computer-supported tasks and goals. This disregard appears to originate from vicious design practices of always counting on the growing performance values of the computational resources and from development concepts praising technology and not focusing on the prospective users. A conceptual change is foreseen only in the event business opportunities for mobile services become very promising.

In terms of what affects the quality standard of multimedia, interactive services, if similar information content, interface, and functionality assets are to be offered for the mobile platform, some application features have to be changed, others, adapted, in order to provide the best service performance attainable to the mobile terminal. Above all, the human factors have to be more intensively considered in the development of applications for an effective integration of these supporting tools in their daily activities and lives: this implies greater regard for the users, their tasks, and the application environment. In addition, any service should be able to account for, adjust itself, and be responsive to the increasing and unpredictable diversity of prospective users and usage circumstances. The achievement of this attribute becomes even more challenging when the service is meant to be the enabler of a social process subject to all kinds of differences.

1.2 Motivation and Aims of this Dissertation

The motivation of this dissertation is to foster the development of more effective application systems to support mobile activities that should promote, above all else, the satisfaction of both the cognitive and ergonomic needs of mobile users. Since the target application scenario is a computer-supported co-operative work, where a mobile worker shall be far apart from a professional peer, there is a further motivating challenge: to accomplish an effective digital mediation to the human-to-human communication process despite the social, organisational or technological differences, which will certainly exist between them.

Based on these motivating challenges, the general aims of this research are:

- To discriminate appliances (especially interaction devices) and communication entities involved in Mobile Computing in terms of usability and appropriateness; and further, to investigate information representation and system procedures that are able to cope with any selected apparatus;
- To analyse representative application cases with the aim to create a set of correlation between their operational circumstances and requisites, and the necessary supporting platform and system features. The expected results are critical considerations for the adequacy and long-term success of any future application target to support mobile user activities; and
- To exploit the former results in the design and implementation of the interpersonal communication tool, taking into consideration the heterogeneous users and their underlying platforms. The emphasis and novelty of the design approach shall be the combined concern for the out-of-the-ordinary "mobile component", the conferencing issues when between asymmetrical parts, and the way both call for adaptive systems features.

1.3 Background and Research Themes

This section presents concise descriptions of select bodies of research and relevant projects related to the theme of this work. These refer to existing findings and solutions, which exhibit similar or complementary characteristics to this work; the described concepts, approaches, and results also serve to position this work in terms of research focus and achievements. Further references will be mentioned in chapters pertinent to the theme and, in a later section of this work, to the description of the developed prototype.

1.3.1 Research themes and position of this work

Since the wireless and portable technologies have stirred up market interest for ubiquitous access to information services, there is an intensive pursuit of new technologies, as well as advances in current technologies, fostered by the prospect of new services and business opportunities (consider recent astronomic investments in Europe towards the third generation–3G–of wireless networks). Nevertheless, apart from the welcome achievements with new functions dealing with mobility and outdoor usage, certainly the performance and quality of the services will always be subject to comparison to the higher levels that users may obtain concurrently from the (equally greatly evolving) stationary technologies. In addition, for a professional use, issues such as security and costs rank even higher. In terms of constrained performance, even more challenging is the fact that the most coveted and advertised new services – photos and video from anywhere – deal with media that are most dependent on the performance and robustness of an underlying platform, whose characteristics may vary dramatically. In this aspect, an additional challenge is that content data and service customisation approaches have a demand difficult to supply in face of the myriad (and heterogeneity) of new platforms and users.

Thus, as never before, Quality of Service (QoS) and adaptation procedures are being greatly addressed within numerous research activities in academia, industry, and standardisation forums with so many interesting variations. In fact, the term QoS has been promoted mainly by all the efforts for optimisation of system components (specially, network traffic) for allowing real-time and interactive media over limited links–a great challenge in mobile computing– and general connectivity problems in an overall network; progressively, and yet not surprisingly, it is being extended to embrace and satisfy users' sense of quality[1]. Even without a clear definition of QoS, and of where the boundaries between quality at system and at application or user level are, any solution towards this goal inevitably requires that, first, one has to learn of the resources available for the service, the resource requirements from the application and users, and then, how to deal effectively and successfully with them. These assessments, considering first and foremost the "resources within" the service (i.e., the human agent and application context) and then the translation of respective requirements and quality parameters into the system level, constitute a focus of this research work and determine the relevant works and literature as references for existing findings and solutions, and further readings.

[1] Usually, Quality of Service is explained and quantified by two basic abstraction categories: (i) system level: concerning technical characteristics dealing mainly with parameters related to network and operating system, ex: bandwidth, delay jitter, packet loss, CPU priority; (ii) application session level: concerning characteristics, which are pertaining to users' perception of quality, ex: quality of a media content (e.g., video, audio), which nonetheless has multiple quality dimensions to be considered. In a video-conference system, for example, the video stream would affect perception by its frame-rate, the size of the video image, the image colour and resolution, level of synchronisation with audio, and so on. However, these levels are bound together and parameter matching has to be performed; as exemplified by Reynard et al. [Reynard98], the dimension chosen for a video medium level will necessarily map to settings at system level, for example, the choice of frame-rate will impact on underlying bandwidth.

In dealing with a service for supporting cooperation, the research field of Computer-Supported Cooperative Work brings with it, per se, all of its multidisciplinary concerns and problems to be considered, ranging from distributed system issues to Human-Computer Interaction (HCI) and social psychology. This research work examines most of the aspects and several contributions from relevant works, but it focuses its effort towards the guarantee of an effective cooperation session (service guarantee at user's level, or session level as mentioned in footnote '1'), attending to peculiar demands and conditions, both at individual and collective levels. This should be assured even when strong operational and personal asymmetries exist among the agents. This consideration differentiates this work, and few related references are found.

Usually, HCI research works related to portable devices are centred on such problems as those arising from the diminishing size of hardware (for example, examining how the Graphical User Interface can be adapted to the dramatically smaller screens). However, a support to mobile or field-based activities requires even stronger considerations to other problems that regard the inconstant and less controllable cognitive and physical usage conditions, and the mobility required by the person while simultaneously operating the device and system. This work resolutely focuses efforts on HCI-related adaptations that shall harmonize the supporting system with these parameters. Factually, 'mobile interaction' is currently a theme in effervescence, after a relatively calm period of discussions on GUI simplifications for 'wireless Internet', and 3D information contents. In addition, new appliances and interaction models are being suggested; these should be: less obtrusive, hands-free, "eye-free", demanding minimal attention, without user-direct intervention, etc. In this respect, many references dealing with new and even outstanding solutions could be cited, but few are found, as in this work, assessing and considering real conditions of use for shaping the user interface.

The next sections present concise descriptions of significant projects related to each of these research themes and relevant for both motivation and appraisal of this work.

1.3.2 Resource awareness and adaptation

In a line of exploration, there are projects dealing with resource management mechanisms aimed at identifying and allocating resources that meet service or application requirements. "**Darwin**" [Chandra01] is an example of a management system for "Value-Added Network Services". It is said to accommodate QoS features with resource management policies for service providers. This means that it would be possible to allocate resources for a certain service (e.g., bandwidth for video streams in a distributed environment) by switching local providers in a seamless way for the clients. To achieve this functionality, Darwin relies on a Virtual Mesh, which is a core abstraction for its resource management, and on various layers like runtime resource managers (control delegates based on routers to allow rapid switching as a function of the network behaviour). Overall, this system tries to optimise the use of resources in a service-provider's company network to enhance availability while maintaining QoS for its clients. This kind of load balancing of resources has its value and a general character that permit supporting almost every application; however, the proposed adaptation occurs far too transparent to the application and so without a chance for an application-specific adaptation.

In another stream of exploration, because some services are not able to influence resource allocation, the investigation focuses on how to adapt services on their provision side, according to customer preferences and the capabilities of the individual terminals accessing them. This is quite valuable in regard to the myriad of new platforms and users willing to access, for example, the World Wide Web (sometimes simplified to just the Web, or WWW); but then, how would it be possible to become informed about the respective customer profiles? Examples of efforts in this area are working activities from W3C (World Wide Web Consortium) groups in respect to mobile access to the Web. The propositions for "**Composite Capability/Preference Profiles**" [W3C] for content negotiation, and standards, including eXtensible Mark-up Language (**XML**) and eXtensible HTML (XHTML), both propose or incorporate mechanisms to help services adapt content delivery to a range of networks and devices. This idea of processing and storing client profiles is also present in this work with an even greater chance for user agency; and because the explored service is groupware, the profile also has to include attributes from the collective level.

In this domain of Internet services, one reference system is "**TranSend**" [Fox98], developed within the "**Daedelus"** project [Seshan96]; it was one of the earliest projects to explore intermediate transformational proxies; starting with the goal to provide on-the-fly network adaptations to users over wireless links, it has evolved into a general system for deploying scalable and fault-tolerant adaptive applications. In principle, the system intercepts HTTP requests from standard Web clients and applies data type-specific compression before forwarding the data; this adaptation occurs in accordance with stored client profiles and media. A case similar in idea, but rather different in architecture and tools, is "**WebExpress**" [IBM, "Networkwithoutwires", at URL: www.ibm.com/Stories/1997/08/wireless4.html], a background service to support a Web browser, and aimed to reduce the number of requests and quantity of data sent over a wireless network. Likewise, it intercepts Web browser requests and provides corresponding data reductions and compressions when returning the responses. In terms of the number of necessary interactions across the wireless network, it contributes to their reduction by maintaining a persistent connection. From these two references, especially the former has provided this work with valuable concepts and ideas concerning adaptation of media content.

A comprehensive work regarding mobile information access and application-aware adaptation is the "**Odyssey**" system (see [Noble99] for an overview of Odyssey and further references to component solutions). Remarkably, this system explores a collaborative partnership between the operating system and applications to monitor and manage resources dealing with multiple resource-concurrent applications on the same host. In this design concept, a central operating system-based facility coordinates the demands for resources from all application systems. The application demands for resources (plus the window of tolerance required) are intercepted and directed to a viceroy that monitors available resources and decides on their usage; for this decision, this viceroy considers quality levels, similar to the media quality dimensions mentioned in footnote '1'. In this model, some adaptation is actually done at application level; the application receives a notification of resources availability and decides itself how adaptation should occur. A significant achievement of Odyssey is the possibility to support legacy software, as well. This support is similarly followed by a middleware component and mechanisms developed within the "**Aquila**" project [Tsetsekas01]. The Odyssey's approach prevents, however, a particular resource control for individual applications, and any managerial process is a local affair, not taking into consideration resources from remote end-points of a distributed systems. In addition, the awareness concept focuses on resources at system level only, and the full automation disregards the user who cannot interfere with the adaptations or is left wondering about the cause of a sudden change.

Another reference project dealing with dynamic management of resources and mechanisms to support mobile applications is the "**GISMO**" project [Schill01]. In early phases of this project, the team developed mechanisms to locate and monitor resources with a later achievement of a middleware platform to support distributed systems 'with' mobile participants (that means, to support not only individual limitations). In later work, they introduced a partitioning model of systems in components distributed among mobile and stationary hosts, and a combination of techniques to solve problems inherent to mobile computing; and more recently, they introduced an approach based on software components focusing on a model for integrated adaptations. A missing feature is still the exploration of resource values or any other requirements (expressed, for example, directly by the users) for a dynamic reconfiguration of the application structure or components.

Coming closer to the author's primary purpose for the concern in respect to resource awareness, a noteworthy reference may be found in research works related to user-oriented QoS issues within the project "**FRIENDS**". In [Widya01], the authors exalt and report a development trajectory starting from the QoS specifications at the level closest to the user's perception–the system interface–(these specifications are most dependent on the task context, role of the users, and the purpose of the task), towards their implementation on a distributed system platform, and their mapping down to the underlying layers–computing and network resources. During this referred work, the value of an exhaustive task analysis was confirmed in order to capture required QoS that should improve likelihood of service usage, and to achieve a better agreement between context and service level establishments. The authors also report on a visual mechanism to monitor delivered QoS for commercial exploitation of QoS-aware services. Such a monitoring mechanism is also an issue in this present work, just with a different objective: to provide feedback and support awareness for the end-user.

Lastly, the work reported in [Arbanowski01] is a noteworthy reference to similar ideas and focuses on considering the "resources within" the service as the core of a communication system design. The authors introduce the concept of "**I-centric Communication"** Systems, where 'I' stands for an Individual and 'centric' denotes that the system should be adaptable to I's requirements, communication space and behaviour, and environment. Similarly to proposals to be presented later in this present work, they suggest that I-centric systems should have the ability to generate and continuously control 'user context' (according to their definition of context) recorded in user profiles, to adapt to conditions in the physical environment, and to run services according to the context and user preferences. For the specification of these profiles, also in a similar vein, they exploit the flexibility and customisations offered by XML. Their reports on results from developed realisations confirm the value and efficacy of such approach.

1.3.3 Co-operative work with mobility

In dealing with the employment of mobile computing in an industrial environment, this work has some similarities to the "**FAST**" project [Ockerman99]. This project is aimed at providing enhanced support and assisted training to the mobile industrial workforce in a factory plant by "outfitting" employees with wearable computer systems systems. In FAST, the major assets for further references are their ergonomic concerns related to the factory setting and the task-oriented organisation in the design of "electronic performance support systems". "**NETMAN**" (see [Bauer98] and [Kortuem99]) is also a wearable system aimed at providing communication and collaboration in similar applications domains. In this project, there is significant exploration of remote awareness for the desktop partner in order to improve the social process; however, less is revealed about system augmentation directly for the mobile user. NETMAN has evolved to a further project named "PROEM", which promises functionality and components to system adaptation; from this, only Web-page notes (see URL: www.cs.uoregon.edu/research/wearables) about group activities were available by the time of the writing of this document.

Current developments in the educational environment "**MetaPark**" [Dyer99] also investigate the employment of wearable computers within Computer-Supported Cooperative Work (CSCW). In this project, the network architecture–MUON–is used for supporting wireless connections from client systems, and there are works in progress in terms of contextual awareness to automate and facilitate data retrieval. However, very few features are reported regarding necessary contracts in respect to the consistency of the shared media content and service among the clients on different platforms. Concerning CSCW using wearable computers, there are several other projects, but for them, a co-located co-operation arrangement is foreseen; hence, distribution of data, information sharing, and interaction techniques face different problems from those presented in this work.

A project very much akin to the idea of developing adaptive collaborative multimedia applications for operation in unreliable networking environments is "**MOST**" (see [Cheverst98] and [Friday99]). The authors also use an application scenario where field engineers would have a gain in operational efficiency by means of a remote access to databases from a control centre and by having the possibility to obtain assistance from members of this centre in a reliable form. An analogous approach to this present work is that they have conducted an extensive requirements capture exercise; and they came up with similar conclusions, namely that it is very difficult to know beforehand, exactly what support groupware for supporting mobile collaboration needs to provide ("different utilities companies, although having basically common requirements, are likely to have differences, and the requirements of these companies are likely to change or adapt over time as working practices change; therefore, the application and supporting platform needs to be designed in such a way that it is readily expandable"). In addition, they similarly investigate facilities to enable users to adapt their style of integration according to QoS-based information (e.g., latency and transmission cost) and when constraints violate the communication requirements of the collaborating group; furthermore, they explore practices of purposely reducing the level of functionality of an interface for a constrained mobile user.

Lastly, research works, such as the one reported in [Gutwin01], are very inspiring in improving groupware usability despite potential problems raised by the underlying networks. Not under the auspices of the term QoS, the authors look at how network delays affect closely coupled group work in real-time distributed groupware. Concentrating on certain kinds of collaborative interactions, they investigate how interaction, conversation, and task strategies change, and the consequent reduction in task performance and system usability, concluding that "unreliable information is often worse than no information at all". At the end, they suggest design approaches to reduce delays or to work around them, adaptation of user interface and interaction techniques according to delay measurements being most praised. It is satisfying to find similar views on the human-factor, that people may be better able to adapt their actions to accommodate a problem if they are aware of its presence and magnitude.

1.3.4 Interaction on the move

A relevant reference of work in this domain is that of the "**Mobile Computing in a Fieldwork Environment**" project [Pascoe00]. This work concentrates on examining the special needs and the environment of application fieldworks, later, reflecting on the HCI features that shall lead to a successful system and be in harmony with the fieldworkers' usage characteristics. These users were identified as having in common an extremely mobile and dynamic workplace, and as specific characteristics: dynamic user configuration, limited attention capacity, high-speed interaction requirement, and context dependency. From an analysis of a particular field activity, they refine selection criteria for devices and interaction modes, and formulate principles on interface design; furthermore, developed interfaces were verified through field trials with a prototype system. Their conceptual approach ("it is the user's activity that shapes the design of our interface") is a parallel element to this present work; they similarly propose comparative tables that would aid in specifying interfaces, and requirements and limitations of the design of new ones. However, a dynamic adaptation of the interface according to the current conditions of use is missing (as reported thus far, they have concentrated development for a single field activity and there are plans in using context awareness to dynamically build interfaces from reusable components).

Another significant work addressing HCI design for mobile devices and applications is "**MOTILE**"; it aims to solve or improve limitations of mobile computers with an application-oriented perspective rather than technology-specific. This approach is demonstrated in [Kristoffersen99], where the authors present their interpretation of the practical problems of using mobile computers out of empirical studies conducted in two application scenarios. In this report, the authors refer to studies on "handheld CSCW", though the whole focus is placed on drawing design principles for the practices of interaction, rather than on the social context of work (CSCW sessions). During these studies, they coined the expression "technology making place" in the user's work at hand, to denote improper approaches to adapt work to the harness of the supporting technology (this term will be referred to again later in this present work). In the end, they claim that MOTILE offers an interaction style for non-conventional use context; in particular, those where task–other than operating the mobile computer–may be the most important, where the user's hand may be otherwise occupied, users are involved in tasks "outside de computer" that demand a high level of attention, and users are highly mobile while performing the task. This awareness and approach is pursed in this present work, as well, given that the characteristics of the work context and users (the mobile part) are very much alike, but here, with the additional focus on the social process among heterogeneous users.

Lastly, a simple–but very constructive work–is reported in [Schmidt00]. The authors present principles and interesting ideas for the design of 'wearable Graphical User Interfaces' (**wGUIs**) based on the simple acknowledgement that, if the user is moving while operating the computer, some restrictions for the user interface apply. Some proposals resulting from experiments with wearable computers and see-through, head-mounted displays have parallels to this present work; these proposals are related, for example, to GUI elements not demanding high accuracy from pointing mechanisms, a reduced complexity of the interface, and concerns about minimal attention demands. The description of future work points to an ongoing investigation of awareness technologies and lends support to the goal of this work in selective adaptation.

1.4 Research Contributions

In this thesis work, there are several considerations and efforts similar to those of the works mentioned in the previous section. Differences emerge mainly in the face of the target services and the substantial concern emphasised by this work regarding the human-computer interaction process (see also [ASantos01]) and the requisites at individual and collective levels within a computer-supported social activity.

Succinctly, the main relevant contributions of this thesis work are:

- Dedicated methods and tools to assess and analyse user and task requirements, as well as candidate technological entities. The advancement with these developments relies on the possibility to work on relations between the diverse requirements, and with their variances, occurrences, and implications;
- Innovative tools to modify information representation leading to optimal data distribution and service viability in the view of extreme network constraints;
- Revealing issues and methods for an intelligent, adaptive behaviour of an application system. Most of the existing works on the design of adaptive systems for mobile computing concentrate their efforts on overcoming technological absences; few of them seem to employ a human-centred approach with a proper concern for the

associations between mobile user and device, and practical application requirements. Lastly, none seek to intersect the issues and effects of remote, collaborative computing. In these regard, this dissertation presents a unique challenge;

- As practical realizations of these contributions, two conferencing systems for supporting co-operative activities of practicing engineers have been implemented and are described in this work. These systems are able to cope with the heterogeneous technological apparatus and serve users with different abilities and roles, and in different conditions of usage; and
- An innovative resource-monitoring tool conceived and implemented to assist the application systems in their ability to adapt functionality and "interactiveness" according to the state of usage profiles and changing operating conditions. Through the description of this tool and an integrated solution–monitoring tool plus adaptive conference system–not just the mechanisms are presented, but also inference rules for their employment.

1.5 Summary

In this section, selected research works and projects related to this research have been presented. The account is certainly far from being comprehensive, not just because of the broad scope resulting from the themes, but, as mentioned before, these themes have become the most 'fertile areas' for research investigation topics in recent years and have promoted an astonishing run on innovations pushed largely by commercial prospects.

Following this introduction, this work is organised in six chapters, including a summarising chapter at the end.

Chapter 2: Mobile Computing and Its Technological Implications

This chapter introduces the concept of Mobile Computing from an application perspective–the tools according to the activity requirements. This introduction is followed by an account of the more relevant apparatus and functional components involved. For each apparatus and component, a short description is presented with the purpose of appointing those characteristics, strengths, and weaknesses that might influence a qualitative delivery of interactive and multimedia services for the mobile user. From these attributes, one would later be able to infer functional components able to handle and adapt application systems accordingly.

The reason for presenting technologies first does not correspond to the order of relevance adopted by the author in the specification of a system. The reason is to clarify terms, attributes, and particular characteristics that will be referred to throughout this work.

2.1 Computer-Supported Mobile Activities

For a person engaged in a nomadic and, worst-case scenario, in a mission-critical activity, having a sufficient set of working tools and supporting material at hand is imperative. Discontinuities caused by the absence of a required tool or by the person being uncertain how to proceed can be very costly and may hinder the completion of the task. If the activity is routinely performed, briefing himself thoroughly for the task helps to prevent this situation. However, if the activity (for example, training or trouble-shooting) is infrequent and has a novel or surprising component, some kind of hindrance is inevitable.

It is a matter of fact that the labour force in modern factory plants is increasingly confronted with equipment and tools tied into highly technological assets, which demand a great amount of working knowledge to be mastered, and for which, it is much too arduous to maintain an updated level of expertise. Pertinent documentation is similarly increasing, which makes it difficult to keep them updated, as well, and for the worker, to simply and permanently carry all the relevant supporting material. To satisfy this problem (for instance, the lack of information at hand), the inclusion of a portable computer in the worker's toolbox could be very successful; the information system would be as mobile as the user, and its benefits could then be available directly at the point of need. If a data transmission channel could be made available, as well, preferably without tethering the person and supporting apparatus with cables, then the worker could also access or modify remote data, and eventually consult someone back at an office. This is another characteristic in current industrial processes: the geographical distribution of their agents; see Figure 2.1 for an illustration of such computer-supported cooperative work.

Bringing effective benefits to such industrial scenarios has raised an earnest motivation for this research work. This pursuit is encouraged and fostered by the recent technological achievements that allow computing-resources to be employed at any location where its support might be of need. These achievements refer to advances in the technology domain called Mobile Computing. Some of the most relevant advances are presented in the following sections.

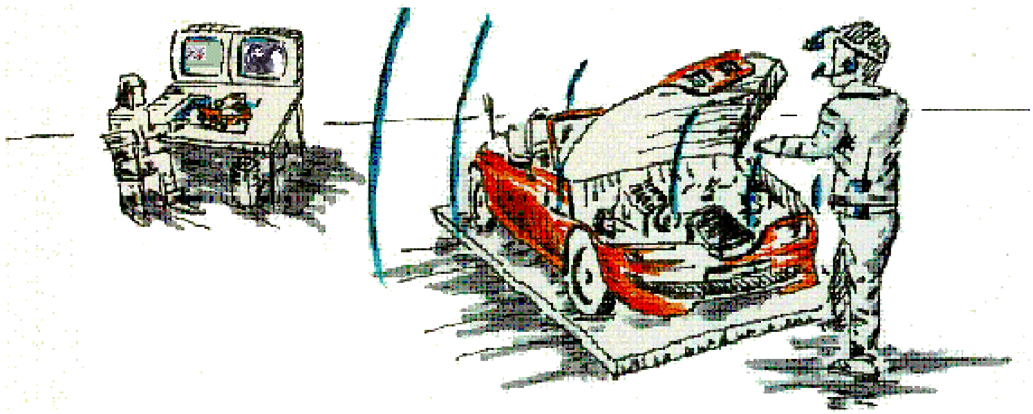

Figure 2.1: More productive work with computational support and remote assistance.

2.2 Symbiosis of Technologies for Supporting Mobility

Mobile Computing is a concept that integrates a series of technologies in the areas of communication and information technology, and whose main ambition is to tolerate mobility of the computer user. This mobility aspect might refer to:

1. a ubiquitous employment of a computer and a service during activities which are not bound to a desk (sometimes called "terminal mobility");
2. the operation of a computer while the respective carrier and user is in movement (sometimes called "personal mobility", because mobility is centralized around the person who uses the terminal to access one or more applications); or
3. a user roaming and accessing information services from different network points, even of different standards (an enhanced "personal mobility" with support for internetworking).

For these scenarios, the required technologies are (not in sequence): (I) wireless communication infrastructures, (II) portable computers, and (III) system tools that allow the location independence of all of their components: data, tools, processes, and the user. Each of these technologies has a different relevance and poses different challenges to the goal.

Concentrating on the first and second usage models, mobility is supported essentially by the miniature and untethered attributes of the hardware and network technology; and, above all, as advocated in this work, by application system features that reveal substantial accounts to the user, as well as the ergonomics of the mobile activity. The need for these features is revealed mainly in a work environment during usage conditions, which compel that a tool–the computer–should not interfere with the fluidity of human actions and should allow for an unobtrusive and safe operation.

Thus, an important and fertile research stream on Mobile Computing can be towards the provision of human-centred systems, which, as postulated by Talbert in [Talbert97], ought to take into account human perceptual and motor capabilities, and to support real practices effectively. Figure 2.2 illustrates the challenging communion between the computer world and the primary activity of the prospective user.

Figure 2.2: Convenient supporting tool for hands-on work.
(courtesy of Xybernaut GmbH).

2.3 Resources for Mobile Computing

Often, the seduction of technological assets and the desire to be in the vanguard of progress are the factors that primarily compel system designers to prescribe novel appliances or technological solutions. Later on, these designers will also labour under the "myth of the infinitely fast machine" (as defined by Dix [Dix91]) and design their systems as if processing response would be always immediate and do not plan explicitly (e.g. a feedback to the user) for slow responses. In the end, the disparity between who conceives and who supposedly gets the benefit of the system characterises the predominant technology-centred design approaches, and is the main cause of product failures. In the case of mobile applications, if basic constraints posed by mobility are disregarded, and if an attentive analysis of the mobile platform is not performed in advance, several product features will later emerge as critical.

In the following sections, some resources for Mobile Computing, those that are closer to the user and activity, will be presented with remarks as to the most important attributes and effects to be considered. Later in this dissertation, these remarks will yield a sort of checklist, as well as recommendations for platform specification. They will also provide elements for application adaptation procedures according to the existing resources.

2.3.1 Mobile terminals

Laptops and Personal Digital Assistants (PDAs) are currently the representative choices when bringing in data processing terminals for mobile computing. Available in a variety of formats, resources and functional settings, their class attributes are primarily reduced weight and size, and the battery power-supply. Furthermore, in order to accomplish a full wireless operation, they are usually featured with built-in or plugged-in wireless cellular or Local Area Network (LAN) modems for networking capability.

A recent trend in the miniaturisation of these devices has not been through the physical shrinkage of the components, but rather through a purposeful reduction of their processing capabilities, as reported by Lettiere and Srivastava in [Lettiere99] about their "CruisePAD" and as can be observed in Berkeley "Infopad" terminals. Both terminals are merely wirelessly extended input and output devices–thin Clients–of a nearby desktop machine that acts as a processing and data-storage server. A disadvantage in this approach is that such terminals must rely far too much on the network connectivity.

Nevertheless, while these devices serve their purpose, the consequent reduction of resources plus the variety of configurations complicate both the wide dissemination of new systems (as experienced in the PC domain) and the migration of those originally developed for the relatively standard desktop platforms.

In some cases, the distinction between processing resources is qualitatively insignificant, such as between a laptop and desktop PC. Nevertheless, the miniaturization of interaction mechanisms (which, when available at all, are mostly adaptations of the desktop counterparts) affects in inverse ratio their respective usability and prevents uniformity on the interface and quality of interactive applications. Classical examples are respectively: miniature keyboards that are practically useless in some mobile or one-handed operations, and miniature displays that dictate limits on the graphical user-interface.

In addition to these intrinsic differences, the field application might also require particular device forms. For example, if the bestowed mobility has to be considered beyond the physical displacement of the user, and include a permanent accompaniment of his body movements, the equipment should be ‘attached’ to (i.e., worn on) the body. This is of special importance for those workers who perform complicated or dangerous tasks with their hands, sometimes even in contorted positions in restricted locations. In fact, a new generation of mobile equipment has appeared, namely–Wearable Computers. This is tightly associated with the pursuit of emphasising human factors in the interaction paradigm and has a hint of a task-orientated and specialized information appliance.

In any case, the following requisites should be considered during the design of an application system with dynamic and adaptive properties, and serve as parameters for the specification of the terminal:

- Appliance: the compactness of portable equipment should not necessarily be a reason for reductions in interaction interfaces; it should foster alternatives;
- Battery power-supply: the extension of a battery’s operating time should not be a continuous quest for the user; a system should warn him when this reaches a critical state and should employ processes with reduced power consumption; and
- Processing and communications resources: as resources are scarce, some form of degradation in system performance is unavoidable. However, the user has an expectation in terms of performance and quality of service, so, the operational resources should be controlled to suffice the respective demand.

Moreover, if the focus on the application context is enforced, certain interaction modes and respective equipment might occasionally represent nuisances rather than benefits for the user: for example, the difficult coexistence of a miniature keyboard with safety gloves, or a touch display in a greasy or dust physical environment. Thus, there are also the following issues to be considered:

- Appliance: the equipment has to be compact, but also robust enough to operate in adverse physical conditions (subject to abuse, humidity, temperature extremes, or dust);
- Appliance: the equipment should offer a safe use and operation, and not be obtrusive to the user’s main activity;

- Interaction mechanisms: the interaction devices should be manageable in any situation and user position; if not possible, alternatives and substitute devices should be provided;
- Battery power-supply: the battery charge should afford reasonable working hours and be able to warn the user when reaching a critical state.

Some other problems associated with equipment for mobile computing are price barriers and a lack of relevant solutions. Examples are:

- quality miniature displays (in terms of colour vividness, fast updating, and 'comfortable' size) are very expensive and have a high energy consumption; and
- miniature devices are difficult to operate: "The human fingers are not getting any smaller."

In a later chapter, the author will present similar analyses and issues based on more specific parameters of an activity and user.

2.3.2 Wireless communication network

Mobility was the igniting idea for wireless communications in the 1980s. Triggered by the success with voice communication systems, there has been a widespread and enormous interest in the technology domain ever since, and great advances towards data communication were achieved in an astonishingly short period of time. Concerning data communication, while the great potential of mobile computing is easy to discern, remarkably, only a few application systems with established success are available. The reasons for this are numerous, major obstacles being the disappointing characteristics, for example, sometimes large packet-losses, limited and varying bandwidth, notable end-to-end delays, and occasional interruptions, of the wireless data communication channels. Aspects that are of less importance for systems suited for current wired data networks suddenly become very important when you put them in a wireless environment. In addition, due to their relative infancy in the computer domain, the costs of use and installation of wireless infrastructures are still relatively higher.

A representative case of overestimated prospect and fail, after immense installation costs, was the first generation of satellites for personal communication (e.g., "Iridium" from Motorola). Here, the established positive image of satellites in terms of their technological maturity and global coverage was considered a convincing enough argument for attracting consumers in and of itself; however, this proved to be a false assessment of the consumer's overall needs, as the cost of equipment and connections were simply beyond what ordinary users could afford. In addition, key characteristics of satellite–their relatively high transmission delay–raised a number of issues that complicated the provision of interactive multimedia services and Internet traffic[2] in similar quality that computer users are used to obtain from physical networks.

[2] For Internet services, it needs to be compatible with the protocol used in the wired world–TCP/IP (Transmission Control Protocol/Internet Protocol). However, TCP has been designed and tuned for networks in which segment losses and corruptions are mainly due to network congestions; but in wireless channels, the main cause for packet loss is the high bit error rate and not congestion as in wired networks. Therefore, the low efficiency of TCP in the wireless channels is a result of the fact that TCP misinterprets packet loss because of high error rate and congestion (in which case it backs off the transmission rate upon detection of congestion). On the other hand, in high-latency networks (such as satellite networks), adjustments of the window size can take a long time and reduce system throughput [Jamalipour01].

Against any odds, the benefits of a wireless connection are undeniable and the massive, as well as potential, demand is the reward for all the efforts. Factually, the development of third generation mobile wireless systems, for example, will enable networks to provide bit rates of up to 2Mbps per radio channel. This capacity will significantly improve packet-data and mobile multimedia applications. In addition, even higher data rates are being obtained with Local Area Networks using novel, short-range wireless technologies. Bandwidth-hungry, real time and interactive multimedia services, such as high-quality video distribution, client/server applications, and database access, will profit most from these technologies.

Below, a compilation of some relevant standards and technologies for wireless networking is presented. The brief description aims to show the variety of possible solutions for the communication environment of a wireless 'user' and a portable computing device, and the respective resource values that the application systems would have to deal with.

- **Bluetooth**

Bluetooth[3] is a short-range personal wireless networking scheme targeted mainly at connecting individual data appliances (for example, printer to a processing unit) within a Personal Area Network (PAN) as a substitution for cables and as an alternative to the languishing Infrared solutions. In comparison to Infrared, a key advantage of Bluetooth is the capability of functioning without a necessary line-of-sight. As a standard–IEEE 802.15.1, it operates at the license-free 2.4GHz frequency band, with a performance of 1Mbps signalling rate and coverage around 10 metres (or up to 100m with signal enhancers).

Considering a worker, who would have to use a computer on the move or in difficult places, undoubtedly Bluetooth responds with a great ergonomic advantage by eliminating cables and allowing interactions from a distance through the minimum necessary devices (i.e., commands with a detached mouse or keyboard). However, despite these valuable prospects, Bluetooth is still struggling to take off, partially due to the slow appearance of device components–chips and adapters–and the dysfunctional coexistence with the radio access solutions currently widespread in office facilities (i.e., interference problems with cable-less telephones, microwave ovens, and WLANs, which operate at the same frequency band). Anyway, as mentioned before, Bluetooth is primarily seen as a solution for connecting devices and not as a networking platform for application systems.

- **HomeRF**

Home Radio Frequency (HomeRF, for short) is a standard designed for home networking that should operate on the license-free 2.4GHz band, with rates up to 2Mbps, and coverage up to 100 metres. Similar to Bluetooth, it is primarily seen as a solution for connecting devices rather than a network platform.

- **IEEE 802.11 Wireless LAN**

Access technologies for Wireless Local Area Network (Wireless LAN or WLAN for short) are intended to provide connectivity for mobile people within certain premises, such as enterprises or domestic sites. In this category, IEEE 802.11 is a relatively new WLAN standard, developed by the Institute of Electrical and Electronics Engineers (IEEE), whose extension–IEEE 802.11b (using Direct Sequence Spread Spectrum technology)–has spurred the market of WLANs and is currently widely adopted. This extension transmits at the 2.4GHz band with published data rates from 2Mbps to 11Mbps (sufficient for the requirements of typical enterprise applications, but limiting for services, such as high-quality

[3] The Bluetooth name and the Bluetooth trademarks are owned by Bluetooth SIG, Inc.

video section, or services with a high density of users), and it offers coverage range around 150 metres[4].

* Note that the increasing number of products that are planned for or in deployment on the shared 2.4GHz band causes serious interference problems between the different devices.

An extension to the standard–IEEE 802.11a–is due to become available in the near future; this shall operate on the unlicensed 5GHz band and offer a signalling rate of 54Mbps, but have a shorter coverage than the IEEE 802.11b. Such performance in data rate will allow, for example, a high-quality streaming video section with additional file transfers, database access, and other applications.

- **HiperLAN/2**

High-Performance Radio LAN Type 2 (HiperLAN/2) is a standard for WLANs that originated within a project by the European Telecommunications Standards Institute (ETSI) for wireless Asynchronous Transfer Mode (ATM). HiperLAN/2 shall operate on the unlicensed 5GHz band, with broadband rates up to approximately 54Mbps and coverage up to 150 metres.

In certain aspects, it is a competitor to the upcoming IEEE 802.11a WLANs. Claimed differences are that, from the beginning, HiperLAN/2 has been developed with support for real-time applications, with a goal of low power consumption, and for a seamless roaming with a variety of network infrastructures, such as Ethernet, ATM, and UMTS. Furthermore, HiperLAN/2 shall support QoS parameters, as for the wired ATM, and security should be provided by encryption and authentication protocols.

- **GSM**

Global System for Mobile Communication (GSM) is a standard for Wide Area Network (WAN) and the technology for telephony that has revolutionized and popularised wireless communications much more than the long existing satellite solutions.

For data communication over GSM networks, Circuit Switched Data (CSD) and Short Message Service (SMS) have been available for a decade, but both still pose high limitations for professional employment and support to multimedia services (mainly due to the access speed of the former–9.6Kbps–and the message length of the latter–160 characters).

Further evolutions, such as the ones listed below in bullets, are on the way to allow significant improvements in services and access to the most coveted services (e.g., mobile access to Internet, file transfers from and to an intranet, real-time and data-rich services), both for personal and professional usage.

  - General Packet Radio Service (GPRS), which is also known as GSM-IP (because it connects users directly to Internet Service Providers), can offer data transmission rates from 19.2 up to 114Kbps. A significant benefit of this technology is that one can always stay connected and may be charged only for the amount of data that is sent or received; it supports a range of billing methods appropriate to the different services that can be accessed.

[4] Air-interface signals are influenced by several factors: environmental variables (such as walls, construction materials, interference sources), topology of and distance between transmitters and receivers, configurations (security, filtering), etc. This makes it difficult to indicate correct range, coverage patterns, or signal strength–one reason why each installation of a new radio technology requires pre-calculations, but also a so-called "site survey".

- High-Speed Circuit Switched Data (HSCSD) can reach data rates up to 43.2 Kbps by grouping several channels. It is ideal for occasional connections to corporate modem pools (for example, for reading e-mail or transferring a file) and for real-time applications.
- Enhanced Data Rated for Global Evolution (EDGE), which will offer data rates up to 384Kbps, will allow GSM operators to use existing GSM radio bands to offer wireless multimedia IP-base services and applications. A step towards the so-called 3rd Generation systems (combining high-speed access with Internet Protocol-based services).

- **UMTS**

The Universal Mobile Telecommunications System (UMTS) is a standard for WAN data services, and a candidate to replace the GSM standard; with it, a data transmission rate up to 2Mbps (at terminals with restricted mobility) is foreseen for mobile applications.

Contrary to the so-called radio techniques, UMTS is not license free, and most probably, the costs for final users will reflect the high price paid for licensing. For this reason, it is already being speculated that if one installs, for example, several WLAN base stations in one backbone LAN cable within certain premises (hot-spot areas), such as in a factory plant, it would be possible to achieve the same coverage as UMTS with lower cost and even higher data transmission rates.

- **Satellite**

Satellite telecommunication is a well-established and reliable technology for meeting mobile and remote communication requirements nearly anywhere over the entire earth. Considering its spatial distribution, it is the ultimate remedy for establishing a link between ground stations, spaced ‘far apart’ by a forest or ocean, or for a quick connection in the aftermath of a disaster or conflict, where the existing communication network has been damaged or does not exist at all. It is not surprising that, for a long time, it has been the only solution able to provide field professionals an instant channel to access or transmit crucial information from remote places, such as in the desert or on an oil platform, or on construction sites or in rural areas in isolated regions, beyond the reach of cellular or fixed communications. For these professionals, the deployment of satellite has being mostly for telephony and for transmitting facsimiles or critical data via portable terminals; here, either, due to the urgency or the lack of choice in the arena of use, the benefits usually compensated for the high operational costs– US $ 2 to 6 per minute–and the low performance, for example, 2.4 Kbps from miniature and portable settings.

In more recent times, with further geographic dispersion of business and respective agents throughout the entire globe, and profiting from the market penetration of wireless communication by land-based cellular networks, communication satellites are a booming trend. Accordingly, their performance and services are increasingly evolving (see for example, soon-to-arrive BGAN service[5]), especially towards conjunctions (i.e., mutual

[5] BGAN: Broadband Global Area Network solution is an always-on wireless packet data service from Inmarsat Ltd based on Internet Protocol using satellites. According to this provider, it will offer 2.5 Generation-compatible data communication with data transmission rates of up to 432Kbps (due in 2004); significant amounts of data will be able to be transmitted within a designated satellite footprint. The end-user will just need a compact satellite IP modem attached to his portable computer. Inmarsat is an internationally owned co-operative that provides mobile satellite communications worldwide (URL:www.inmarsat.com).

extensions) with other terrestrial phone and data wireless networks, and as a networking platform for content-rich mobile application systems.

Nevertheless, as mentioned before, for an application system that is not prepared to deal with the effects of a constrained network, restrictions of use remain the low capacity and high latency; yet for an all-purpose and all-man deployment, restrictions to use remain the high communication costs.

The Communication Environment

As presented in the previous items, there are several solutions to offer wireless connectivity 'around user mobility'. Also, with a proper combination of solutions, such as Bluetooth, HiperLAN/2, and UMTS, a complete communication environment could be provided. The first would form a Personal Area Network (PAN) around the personal computer device or at home; the second, a Local Area Network in an industry environment, in a so-called SOHO (Small Office–Home Office), or in a public hot-spot environment; and the third, a Wide Area Network (LAN) for the urban area in general or during field-based activities (see Figure 2.3 for an illustration).

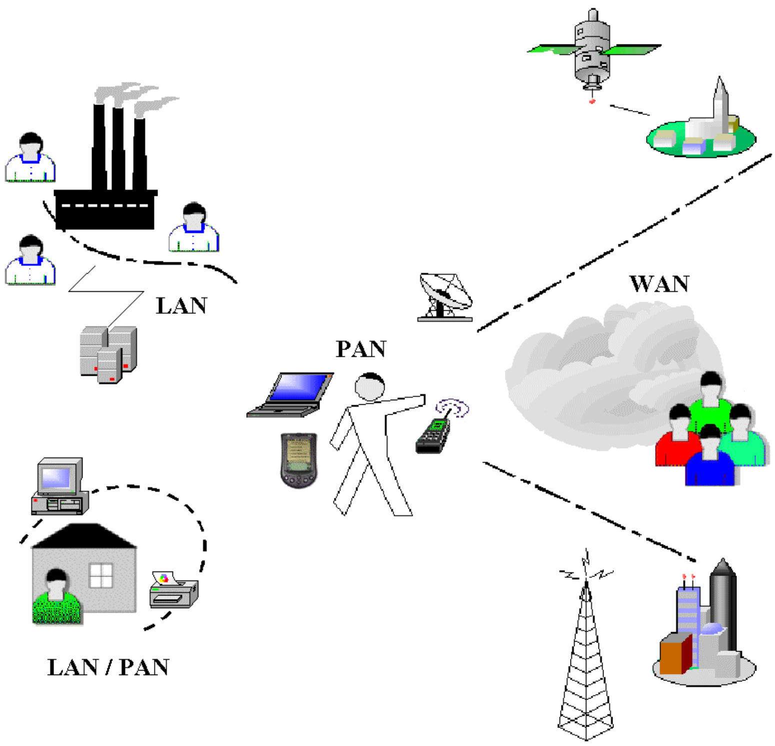

Figure 2.3: The diversity and alternating forms of holding a connection for an electronic communication.

For an application system, these alternatives facilitate, expand, and affect the purpose and functionality of a system. However, they are a means to an end; hence, for the designer, the task is to monitor and fit the performance parameters into the requirements of the application system needed by the user during his activity.

A significant and illustrative argument for this adaptation requirement is revealed by the paradoxical impact of improvements on wireless network services, such as with GSM: the more available the bandwidth, the more variation of bandwidth to deal with! This is because mobility of the user is unchanged regardless of the improvement, causing the application system to experience radio shadows and interruptions on the heels of his changing locations. Thus, the bandwidth can still drop to zero (or close to that) for short periods of time. Also, in the situation where the user is in a crowded cell of a network base station, the network will not be able to provide the desired resources. Therefore, instead of a range of 0 to tens of Kbps, the bandwidth variation would be from 0 to hundreds of Kbps. This requires the application to be even more flexible and adaptable when it comes to bandwidth.

The following issues are to be considered in the system design:

- Together with user location, the type and quality of the media will specify the requirements for data communication; the quality of the service will be affected by the available resources;
- If the cost of use of the network is significant, the user should be informed during the operation process;
- Disturbing signals should be possibly recognized and overridden; on the other hand, care should be taken to avoid negative interference to surround devices (such as medical equipment or any controlling machines); and
- Concerns related to data security, privacy, and the possible affects of radio waves on human health are diverse and relative. It is important to remark that they might yield to cognitive loads that can influence the user’s ability.

2.3.3 Appliances for context-awareness

The context behind a computer-supported activity can be perceived from different perspectives, usually depending on the scope one wants to attain or explore. These perspectives might range from the work domain that requires the activity, the physical environment, or to all the circumstances, people, and apparatus involved in the activity.

Assuming context as the work domain only, not surprisingly, a system tool is developed with a greater focus on the system environment and processing performance than on its user and the supported activity; eventually, in some cases, these tools might deal with the physical surroundings from the perspective that they were targeted to process physical phenomena. However, when the activity to be supported involves “terminal and personal mobility” (as quoted in section 2.2), the concept of context is forcibly expanded by the changing usage environments and situations; in some cases, the physical surroundings might actively interact with the system tools or even explicitly prescribe the creation of these tools.

Providing that an application system is able to obtain and adapt to specific contextual data, as for this broader concept, these data would help to improve user interaction and to correct abstractions made during system design. The provision of these data can be accomplished in various ways:

- via extra appliances connected to the portable computer, such as electronic sensors (e.g. for evaluation of lighting conditions) or components of positioning systems;
- by an active surveillance from the application system that would look for and identify certain markings, such as bar codes or radio-frequency tags installed in the surrounds or on specific objects. An alternative, independent of such pre-prepared, smart surrounds, would be to enable and train the system to identify entities on the captured video images (pattern recognition based on memorized data); and
- by a direct questioning of the user (example, sense of comfort or usability with the ambient lighting conditions).

In respect to sensors, the variety in terms of functional goals is enormous, and the individual utilities are dependent on the target application. In terms of location data, a very popular supporter of context-awareness is the positioning system (GPS); this system will be briefly described in a separate section. Nevertheless, considering mobility also as an important specification factor, the 'secondary' characteristics of these devices, such as size and weight, and power consumption, should not be forgotten.

The second form of data provision requires that all the entities to be handled are known beforehand and that the supported work is performed in controllable conditions. As pointed out by Gellersen et al. [Gellersen02] when talking about "indirect and direct awareness" of context, the reliance on such fixed infrastructures limits the exploitation of contextual data to specifically equipped smart environments. In addition, especially for the mentioned alternative, the respective processing is extremely resource consuming for a small portable computer.

Lastly, the user input should be done scrupulously, because it increases demands on manual interaction.

Global Positioning System

Global Positioning System (GPS) is a satellite radio-navigation infrastructure developed and maintained by the U.S. government. While it was designed for military purposes, currently it is widespread in civil usage for outdoor positioning. Orbiting satellites send specially coded radio signals to earth and the GPS receivers on the ground can collect and convert the signals into position, velocity, and time information (four GPS satellite signals are needed to compute positions in three dimensions and the time offset in the receiver clock).

A nomadic field professional, whose geographical position is an important piece of data or a factor throughout his work, has the possibility to significantly improve productivity by integrating a GPS receiver into a portable computer. Exploring the computational abilities, more data could be systematically captured and even transmitted to a remote processing unit or to someone following the activity's course. Nevertheless, often it is not the position itself that constitutes immediately useful contextual data, but rather additional information that can be inferred by correlations between position and attribute information (such as the name of a factory building) that could be performed with more frequency and depth. At application system level, these data enable both adaptive applications and context-based services.

Concerning the exploitation of positioning data, one has to consider that GPS services offer accuracy in tens of metres (actually, only with specially equipped receivers and keys, and until May of 2000, the accuracy was even intentionally degraded for civil users by the use of 'Selective Availability'). Other sources of position data, less accurate but practicable even in indoor applications, are GSM services, with accuracy in the range of hundreds of metres and UMTS, in the range of tens of metres. In the particular case of indoor application environments, the alternative solution has been previously mentioned; this could be based on radio or infrared cells installed in the environment.

2.3.4 Power supply and autonomy

A fundamental element for mobile terminals is the battery power-supply. For a better efficiency, this should afford at least the outlined working hours for the user's task, plus the effects of the exposure conditions (e.g., temperature, humidity). Hence, especially when this task is far from office facilities, the user should not have to carry several battery sets, or interrupt his work to load one (if a power supply is available at all), or be surprised with an application shut down.

Existing smart batteries go in the right direction by being able to report their charging status, temperature, chemistry, etc. and they can predict their own useful operating time. As a complement, currently, there are commercial applications that can realize this control and visually inform the user of these values, ending the guesswork that has long plagued users.

Nevertheless, purely informative warnings or the apprehension about the diminishing power supply would just serve to grab the user's attention and increase his cognitive overload. An application system should be automatically responsive to the battery status, for example, reducing the power consumption by using alternative algorithms, or starting preventive safe procedures.

2.3.5 Security

The concerns for security are related to the fact that the mobile terminal and radio network introduce severe problems in regards to the loss and theft of equipment, and the protection and control of information access.

First, the integrity and validity of the data, and the safeguarding and control of access must be ensured. In the case of loss or theft of equipment, it should be possible to interrupt the service offering and the localization of the access command; but, again, this possibility is subject to misuse. In respect to the equipment, it is necessary to have user identification for the apparatus itself and for the services. If not, it should be possible to interrupt the delivery of services and the localization of the access command; but this latter possibility could also be misused to breach privacy.

Concerning the network and data security (for example, in the case of dealing with personal data or user profiles), data encryption together with user authentication might be a sufficient solution.

2.3.6 Social acceptability and personal concerns

A user has to feel comfortable when making use of a service apparatus; otherwise, the promised support will be counter-productive. This feeling refers both to physical and mental comfort. The former can be bestowed by attributes associated with the physical relation human-machine; these are, for example, reduced weight, ergonomic form and user-friendly interaction mechanisms, or even safe heating dispersion.

The mental comfort is more abstract and has a personal aspect; typical vexations refer to operation complexity and concerns related to the aesthetic, safety awareness (for example, due to breakable parts close to the eyes or to work regulations), and privacy (for example, with voice-input, using the system in public among possible or supposed observers). Harmful heath effects, as a result of exposure to radio frequency radiation, has also become a significant concern that starts to cause user aversion to wireless devices (mobile and fixed transmitters); see German research program "FGF", (http://www.fgf.de/), and projects "INTERPHONE" and "PERFORM-A" within the European Union's 5th Framework program, (http://dbs.cordis.lu/).

2.4 Closing Words

In the previous sections, relevant technologies for enabling mobile computing have been presented. Several others, such as extended protocols (e.g. mobile IP), agents, network and system architecture, databank distribution, middleware, etc., are of equal relevance and challenge, and are subjects of intense research. The ones presented here are those closer to the interface between the user and the supporting apparatus for his activity. These will also be the technologies that will be referred to and handled most in order to enable the appropriate support for mobile activities.

When dealing with a conference system for remote assistance (as specified in a later chapter), the counterpart of the mobile apparatus will be a full-featured desktop PC wired to high-speed and reliable core networks. For the desktop apparatus, the technology involved has not been explicitly mentioned here, as it is considered well known and comparatively plentiful, not posing constraints for the system and user.

Chapter 3: Data and Service Architectures for Mobile Computing

Similar to the analysis and specification of hardware and network technologies for mobile computing, digital data and information content also have to be selected and tailored for a mobile implementation. This is because the limitations of those technologies project performance values similar to those of the past onto current system specifications. Therefore, if an application system is also targeted for a wireless platform, careful selection of the data format, well-planned structuring of the content, effective exploration of user interaction, and skilful data handling methods are actions to be strongly considered. This kind of recommendation sounds obvious, but their realisations have to be pursued more intensively, because the wireless platform and mobile context aggravate the usual problems dealing with the amount and traffic of data. For an information service for public use, the resulting quality will be clearly perceived by the mobile users.

In this chapter, the author describes investigations of data format and of the provision of information content for multimedia interactive services for the mobile and wireless platform. The goal was not to establish criteria for the selection of media according to message goals or cognitive issues, but rather to test and observe the effects of acting towards data format specification and forms of structuring the content data on the performance of a service. This kind of concern or practice is usually despised by content designers, or just neglected in favour of creating an appealing product and on the preposterous faith that technological advances (or user investment in resource upgrades) would surely lessen any potential problem. The developed concepts and experiments are described with a prototype realisation, concentrating on graphical information content and also attending requisites of a major co-operative project.

3.1 Introduction

Over the latter decades of the computer era, users have grown accustomed to accessing elaborated multimedia interactive systems, making up the modern information services. Mostly to be aesthetically pleasing to the service consumers, these systems make use of a combination of media forms, such as text, pictures, audio, animation, or video, plus ‘hyperlink’ structures. In addition, compelled by market competition, system designers increasingly enrich their service in terms of presentation and functionality, with a flagrant disregard for users, carelessly taking for granted the capability of the foremost available computers, abundant bandwidth values from the communication networks, and standard usage and interaction paradigms.

Nevertheless, the distribution and success of these multimedia services (rich in presentation features, but ‘heavy’ in content data) face severe problems with regards to the myriad of novel apparatus and users trying to access them, especially those from the mobile and wireless scenario. In this respect, problems arise mainly due to the performance limitations of the portable computers and the current wireless communication networks (for example, GSM) that significantly affect and constrain service performance and interactivity. And, although technological innovation can extend the boundary of these constraints, it also tends to create opportunities that quickly fill up the new capacity.

Yet, a compulsory step backwards in service standards would create tension in the value network surrounding the services (i.e., infrastructure manufacturers, content providers, wireless operators, and handset manufacturers) and would have negative effects on (overall) user acceptance. Certainly, it is frustrating for a mobile information user to find that his newest gadget cannot display images or video with the quality he relies on from desktop computers, or to realise that the retrieval of remote files is now something both costly and excruciatingly time-consuming to process. Technologically savvy users, aware of the limitations of wireless platforms and the possible glitches, might be forgiving in respect to a lower service performance and the longer latency periods in acquiring data. However, there is always a patience threshold or even critical situations when data is urgently needed.

Valuing the business opportunities for wireless data services and with the promising next generation of wireless technologies, service providers are starting to focus their attention and efforts, not only to create new services, but also to review system design assumptions and provision methods, considering the mobile component of the service. The quality of the service not only refers to what one might be able to see, but also to pertinent data and functional components, which are aware of and respond to the platform capacity.

In this investigation, concepts have been studied, implemented, and tested with the challenge to guarantee an effective provision of attractive multimedia data and 'interactiveness' over a wireless platform. The following sections describe this work (see also [ASantos98]).

3.1.1 Choosing a media form

Usually, in the process of developing a new information service, designers first decide on the information content and the interaction level to be provided to the users. Afterwards, the media form for expressing each of those information and the interaction models are selected and specified. However, often this choice is primarily based on a mixture of design style, presumably appealing quality, trends, and, at best, knowledge of thumb-rules for user interface design. Occasionally, these aspects suffice for the provision of services to the entertainment sector, and for capturing the attention of advertisement-sensitive consumers, but the step towards guaranteeing quality to a service target as a supporting tool for professional activities requires more than praising innovation, attractiveness, and futuristic technology.

Anticipating subjects that will be treated in greater depth in a later chapter, the author stresses that the choice of the media representation form should also consider technical and cognitive factors of the 'usage profile' (i.e., user, task, context, and platform). This is especially true for tools to support mobile activities, which are subject to the limitations of mobile platforms and interaction constraints. Examples of cross-conditions to be considered are listed below:

- Video sequence is the medium for presenting time-dependent events and for sharing awareness of the progression of an activity. However, the fidelity of the message to be conveyed depends on a tuned presentation and data transmission rate. Furthermore, it implies on large amount of data for storage and transmission and requires non-standard software and hardware. A set of relevant pictures (from selected video frames) could be considered as an alternative for sharing awareness.
- Audio from a remote partner's speech is as a transient phenomenon (persist just in the memory of the receiver); therefore, it is difficult to browse and to repeat, but it is a quite natural mode of human relation and so is quickly assimilated. However, similar to video, the fidelity of the message depends on a tuned presentation and data transmission rate and it implies a large amount of data for storage and transmission. Audio from a recorded speech or synthesised text reading is a very useful supplementary channel when listeners' visual and haptic skills shall be focused elsewhere. Both audio natures divide attention in time and require non-standard software and hardware.
- Graphical metaphors (for instance, by using "affordances"–intrinsic properties–of visual objects at interface objects) are quickly 'spotted' and abridge message expression. These are excellent interaction elements, considering the brevity of time a mobile worker would spend operating the computer. However, perception and understanding depend–among other things–on cultural background, age, visual impairment, and context association. Textual messages could be reasonable

alternatives, but require more attention and perception time, and may be unreadable on small screen devices. Audio or voice output compensates the user's temporary loss of sight or visual impairments, but may be ineffective in a noisy field environment.

- Voice input allows for a hands-free, and sometimes 'eye-free', operation. However, this requires the system speech recognition functionality, which usually consumes too much energy from a battery-supplied device; in addition, it may become useless in a noisy environment, requires a training phase from new speakers (by frequent ones, a temporary cold or emotion can cause recognition problems), and disregards privacy.

  Keyboard and mouse input should be considered interaction alternatives.

- A flexible[6] interface helps to support and adapt the interaction between user and system to user preferences and to overcome situations of constrained interaction. In addition, a simultaneous, dual media interaction (for instance, output expressions) may complement a message and accentuate critical ones (for example, warnings or attention triggers).

It is beyond the scope of this present work to provide a table with ultimate indications for the most appropriate media form for each information content and usage profile. Also, evaluation of perceptual aspects, such as arousal or remembrance effects of each representation mode of data, would be a work in itself and requires a deep knowledge of other science domains.

The aim of this section is to examine issues related to the media choice, whose effects are now exacerbated by the agencies of the dwindling resource values revived by the mobile platforms. Nevertheless, interface design is a creative process and does not adhere easily to rules. One cannot expect, for example, to convince an architect, in the moment that he puts pencil to paper, to give preference to symmetric and straight construction elements, because these are easier to build afterwards. Similarly, when preparing presentation slides, it would be difficult to discipline anyone to always check the size of the file before including a picture or any other media entity, with the foresight to costs for e-mailing them and storage space requirements.

Thus, for a specified media form, one conclusion is that procedures for rectifying eventual problems with this choice should be sought instead. These procedures refer to a work on the respective data format, and to adaptation functionality aimed to strengthen or overcome weaknesses of a media in certain situations and to respect user preferences. These are described and evaluated with a prototype realisation in the next sections.

3.1.2 Choosing a data format

Normally despised in a service design process, the choice of a file and data format for a media content is often made solely by seeing how widely supported the format is by software suites in the target platforms. In the worst case, the designer is simply compelled by the few options offered by the authoring tool. Thus, the size of the resulting content files, that means, the amount of data that will have to be exchanged at the user's expense, or the cost for processing the respective data (i.e., battery charge), are seldom deciding parameters. Now, with the popularisation and numerous configurations of mobile platforms, the negligent habit of pushing the cause of any degradation in system performance onto the user's affordable resources puts the service offer in jeopardy.

[6] Flexibility refers to the multiplicity of ways the end-user and the system may exchange information. This is affected by features, such as, modifiability of the user interface, multi-threading ability of the system, and possibility to substitute information representation.

The adoption of a file and data format should also be based on the characteristics of the encoding and its structure. These factors directly affect the transmission time and costs, especially if the respective file has to be distributed in a low transmission rate channel, and depending on the structure, this might also grant a better control and handling of the content. Furthermore, functional features of certain file formats can provide more effective provision processes; for example, by sharing the viewing of an image during a conference, the transmission and local magnification of a vector image would be more effective than the transmission of a size-equivalent raster image.

In the early days of the World Wide, for example, the euphoric, unconcerned attitude of content designers sustained a massive inclusion of pictures in the Web pages, with a predominance of bitmapped-based images. The corresponding amount of data to be provided resulted, therefore, in relatively large files. Hence, the service delays and respective transmission costs, when images were included in Web pages, were points of recurring criticism, especially from the emerging market of personal computer home-based users accessing the service through low-bandwidth modems. Recently, with Web services being offered to cellular phones (which currently still implies small monochromatic interface screens and 9.6Kbps transmission rate), several differentiating service concepts had to start being considered; for instance, provision of visual contents with images in format and quality according to the resource profile of the accessing device, or even without pictures.

Continuing with graphical media, more specifically static images as a reference media form, the following requisites and considerations could be applied in the format choice with a view to later optimisation processes:

- The format should:
    - offer the possibility to hold images at different levels of resolution for selective provision;
    - support compression options for reducing the volume of data;
    - support working up with resolution and colour depth for reducing the volume of data;
    - not be operating system-dependent for cross-platform distributed systems;
- A binary encoding is quick to encode and decode and yields small data files for storage and transmission; and
- Vector graphics-based images are usually more compact than the equivalent bitmapped image; in addition, they support valuable methods for visualisation, such as, progressive parsing and displaying of data, different levels of details, and loss-less magnification.

If a convenient format is chosen, then there are still further processes to be investigated towards an optimal provision and handling of the information content, while observing the constraints of the operational environment. Within a co-operative R&D project called MOMENTS, such studies have been performed with respect to vector-based images for Web interaction, and handling tolls have been successfully implemented and tested.

These achievements are described in the next section, though only to the extent and detail consented to by the project contractors for the publication of the research work of the author [ASantos98], and the author and his colleagues [Belz97] [Gerfelder98].

3.2 The Project MOMENTS

The Advanced Communications Technologies and Services (ACTS) project–MObile Media and ENTertainment Services (MOMENTS)–was an applied research co-operative work, whose main objective was to demonstrate the technical feasibility and practical viability of a wireless media highway for the distribution of advanced multimedia products. Further aims were to contribute to the understanding of the users' perception of the values of wireless multimedia services, to identify how commercial exploitation of the services using third generation systems could be accelerated, to create new enabling technologies, and to make valuable contributions to standardisation.

In the next sections, the author outlines relevant concepts and enabling tools developed both alone and with colleagues, for an effective provision and handling of vector graphics and animation contents through a poor and unreliable channel for data transmission, such as GSM. These concepts and tools, though not targeted in principle for a conference service (the system case of this research), served to exercise adaptation and forms of distribution of visual contents to constrained mobile end-terminals (literally, some of them have been integrated in the prototype conference system described in later section). Also, they have provided a good experience in system features, such as automatic system modification, and have promoted concerns to what it is currently labelled as Quality of Service.

3.2.1 Contemporaneous related work

The project MOMENTS has drawn influences from and related to several research works in the context of mobile computing. Also, due to the complete scope of an application service, from market analysis to content authoring, or from client-server protocols to a payment control system, overlapping issues had to be solved by combining experiences from project partners with diverse research focuses. Yet, the developed procedures for the provisioning and processing of graphical contents were unique and innovative in their goals and achieved results.

Complementary ideas to content provision could be found in “Caubweb” from Lo Verso and Mazer [Verso97] with respect to controlled caching of information contents for off-line browsing. Such a procedure would increase the availability of information, and reduce the latency of servicing requests. However, any attempt to approach augmented caching procedures for the user had to meet with the disparity of interests among the content and service provider project parties in regard to copyright issues. A case of ‘increased availability’ has been implemented, however, within navigation actions, where internal functions would automatically pre-fetch map tiles adjacent to the one being consulted, without user intervention.

Adaptive features, allowing the application to dynamically adapt to resources or network profiles and conditions, were not extensively addressed as in “Odyssey” by Noble et al. [Noble97], or by the Daedalus group [Seshan96], roughly because the prototype service should take a homogenous platform for all the users for granted (a ‘device-specific’ approach, as mentioned in the project “Digestor” [Blickmore97]). Though objected to by the author, this was a project assumption. Research efforts on adaptive features, such as from the former reference, were resumed and intensified afterwards; these are emphasised later in this thesis work.

In the aspect of reducing the amount of data while maintaining perceptual fidelity to the information content, a procedure has been implemented to generate content tiles in real time with the level of detail in accordance with a stipulated size and information type. The feasibility of this kind of content ‘distillation’ and ‘refinement’ as defined by Fox and Brewer in [Fox96] depends, however, on user acceptance regarding the latency introduced by this process.

Finally, “WebExpress” from IBM, contemporaneous to MOMENTS, has advanced since then in an inspiring client/server architecture aimed to reduce the number of requests and quantity of data sent over a wireless network by using caching, data compression, and data filtering techniques. However, the service did and does not offer data format and content-specific procedures.

3.2.2 Integrated handling of graphics formats

For the projected services to be offered by MOMENTS, a content shaped by means of a congruence of media formats, especially visual content, was of great significance. Furthermore, from the very nature of the services, they had to provide the users with a great interaction possibility as participants in the service events and for the refinement of the information content.

Work tasks were dedicated to evaluate and compare graphical contents in different formats, taking as parameters the adequacy of the format to represent the information, and the compactness of the encoding for the low bandwidth communication environment, along with handling and interaction possibilities. The attributes mentioned in section 3.1.2, plus aspects concerning user interaction, rated a combination of vector graphics highly. These have characteristics (e.g., geometrical entities which can be individually identified, evaluated, and grouped) that facilitate the implementation of sensitive objects, and of the idea described later, of layering information contents by thematic arrangements and for the partition of the respective file.

Therefore, an innovative plug-in for WWW browsers has been conceived and developed with features for handling and displaying graphical contents composed of multiple vector graphic formats. The media-handling tool of this plug-in is responsible for parsing content data in several vector graphic formats and can uniformly encode the information in a unique scene graph. A typical example of a scene graph of the developed prototype service was composed of a scene description in Virtual Reality Modelling Language 97 format (also know as VRML 2.0) or in VRML 1.0 for the 3D objects, plus animation effects, and a background image in Computer Graphics Metafile (CGM) binary format. Moreover, the scene graph would remain open for further inclusions of additional graphical components.

One advantage of this integrated handling referred to the display tool, which could be unique for a scene graph passing over the diverse graphic formats of the content files.

3.2.3 Dynamic content generation instead of an ‘overweight’ content

In the previous section, a set of rules has been presented, which should be of high concern for every content provider. Selecting a data format or a suitable combination of formats, with regards to the compactness of the resulting files, improves the data access not only for users of mobile platforms, but in general.

Assuming that an information-content has been defined, a set of service implementation methods and techniques has been conceived for the content providers. These methods and techniques would allow them to re-structure the service content and sustain access and provisioning according to a user profile. That means an elementary simplification of the service in general, due to those users with poor processing and networking resources, would not have to be considered (users with richer resource profiles should not have to suffer the penalties).

A form of preparing a service-content is to structure it in compact, but comprehensive information entities, which could then be progressively loaded if necessary. This idea of structuring and linking contents resembles the goal of hyper-structures within the WWW, though the aim here was not to offer a convenient and inviting entry to related information contents, but clearly to provide stepwise access to small amounts of complementary data or more detailed parts of a content. Thus, the user could have the chance to avoid receiving an 'over-weight' content all at once, with potentially superfluous data. At the same time, this procedure would relieve the data handling operation on a mobile terminal and the transmission. Following each specific request, the plug-in mechanism on the user's side would progressively build up the graphical content by integrating the composing files.

Another form of adapting the service for networking constraints would be to prepare a lean basic scene and instructions for additional scene components. These components would be dynamically generated, either on the server or on the client's side, and integrated according to the specific application states or actions.

The respective implementations are presented in more detail in the following sections.

Progressive Scene Construction

This procedure allows for a dynamic assembling of different 2D and 3D content files in a unique scene graph. This feature has a great impact on the creation of services; for a content provider is free to conceive skilful services, whose graphical contents might originally be far too large to be distributed over wireless networks. The provider can split up one content and re-arrange it in several small self-contained information pieces of information content.

According to this procedure, each of the files is to be sent by the service provider upon user request, and the plug-in, on the client side, would parse and integrate the content of those new files in the existing scene graph on the display.

Figure 3.1 shows the process of successive loading and displaying of files with 2D and 3D vector graphic contents within the MOMENTS service "City Information". Within this service, 2D vector graphics have been specified for the presentation of maps, whereas 3D vector graphics and animation have been specified for the representation of objects of interest, such as hotels, restaurants, etc. In addition, for the content presentation, a layering approach has been implemented; that means, associated information contents (e.g., hotels, restaurants, or cinemas) are grouped in conceptual layers, according to the service context they refer to, and are to be individually provided on request.

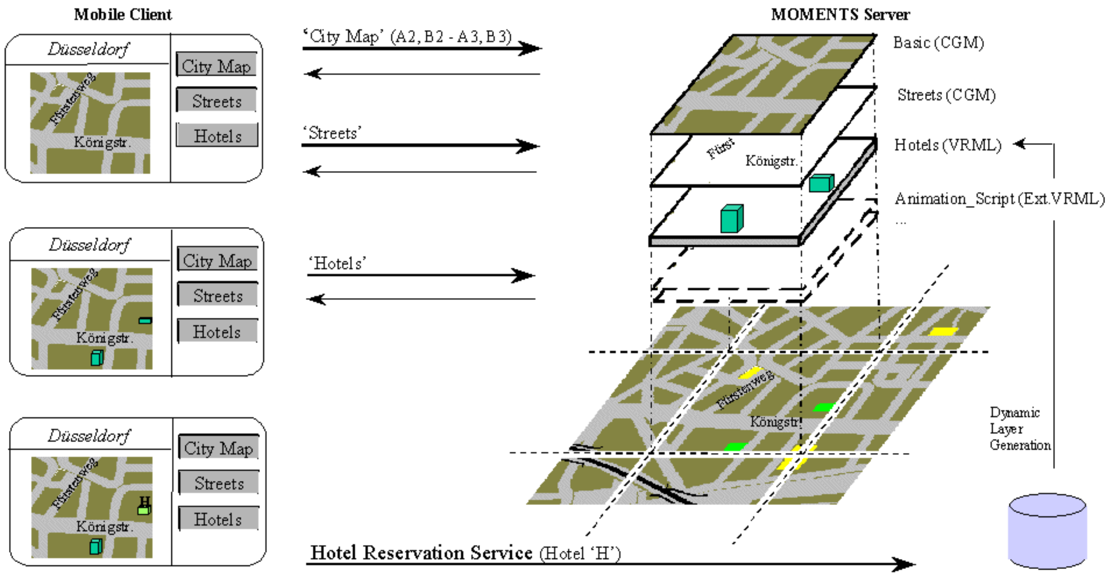

Figure 3.1: Dynamic integration of scene components into a scene graph.

In the "City Information" service, a user wanting to find service buildings (e.g., hotels) near his current position starts by requesting a map focusing on his current geographical location. The service discovers the user's location based on data received from the GSM service (the currently active base station) attending the user's cellular phone. This data is automatically sent to the service server, which evaluates the base station information and identifies it by performing queries to a database that stores geographical information from each base station. This geographical information is then sent in real world co-ordinates to the MOMENTS client at the user's terminal. The service plug-in checks whether it has to request a download of the corresponding map tile (its CGM file[7]) or whether it is are already available within the scene graph. A prerequisite for this mechanism is that the plug-in must be operating on a predefined co-ordinate space, which is based on geographic world co-ordinates, and each map tile has to include the information on its specific location within the entire co-ordinate space. Therefore, the plug-in is capable of assigning the correct position of each map tile within this predefined co-ordinate space, as well as setting up the requests for downloading a missing map tile.

Only after a further request for more details, such as street names, is the basic map tile then complemented with a layer of the corresponding details; this information layer is also coded in a CGM file. Both graphical layers are combined and presented to the user. Following a further request, for example, for available hotels, a VRML file is dynamically generated (with the tool described below) with 3D objects representing the "real-world" hotels in their respective locations (animation scripts may also be integrated) and is sent to the user. Upon selection of a hotel representation, the service will continue with further interaction dialogues (for example, for accommodation facilities, connoisseur suggestions, etc.)

[7] The process of generating this CGM file involves converting the road environment-related information of a world region coded in Geographic Data File (GDF 3.0) format into graphical data in CGM binary format for visualisation. A pipeline of automated procedures extracts information of interest out of the GDF feature catalogues, organizes them, observing the approach of layering per information content, and generates the CGM files; each of these files corresponds to a tile (regions within specific world co-ordinates) for each of the requested information layers. The automated procedures for data extraction and layering by content were developed by group colleagues and are described in internal project reports.

In the aspect of further reducing the amount of data, a procedure has been implemented to generate map tiles in real-time with a level of detail in accordance with a user-stipulated size and information type. The effectiveness and usefulness of this refinement depend, however, on the user's acceptance of the latency introduced by the process.

Object Scene Generator

A tool named Object Scene Generator (OSG) has been developed for a dynamic generation of new scene components according to a list of objects and respective attributes, and according to pre-defined VRML-based template files. Integrated in a service, it allows for the extension of a basic graphical content with relevant components generated on the fly just after specific user request. This method is very constructive in helping to avoid traffic of "overweight" information contents. The process is described in the following paragraphs.

In the system plug-in mentioned before, the user would ask for complementary information to the map tile currently on display. A URL request is set up and sent to the service server, which uses the OSG tool to create, on the fly, a graphical layer out of an object database (containing geographic positions and other pertinent attributes). The database procedure makes up a list of the objects composing the information layer, and, according to the object categories (for example, hotel, restaurant, theatre, or train station), it assigns the respective graphical templates. Upon receiving this input, the OSG tool generates a unique VRML scene (an information layer). The resulting VRML file is then compressed and transferred to the client side, which parses and integrates the new elements into the scene graph on display. Figure 3.2 illustrates this process.

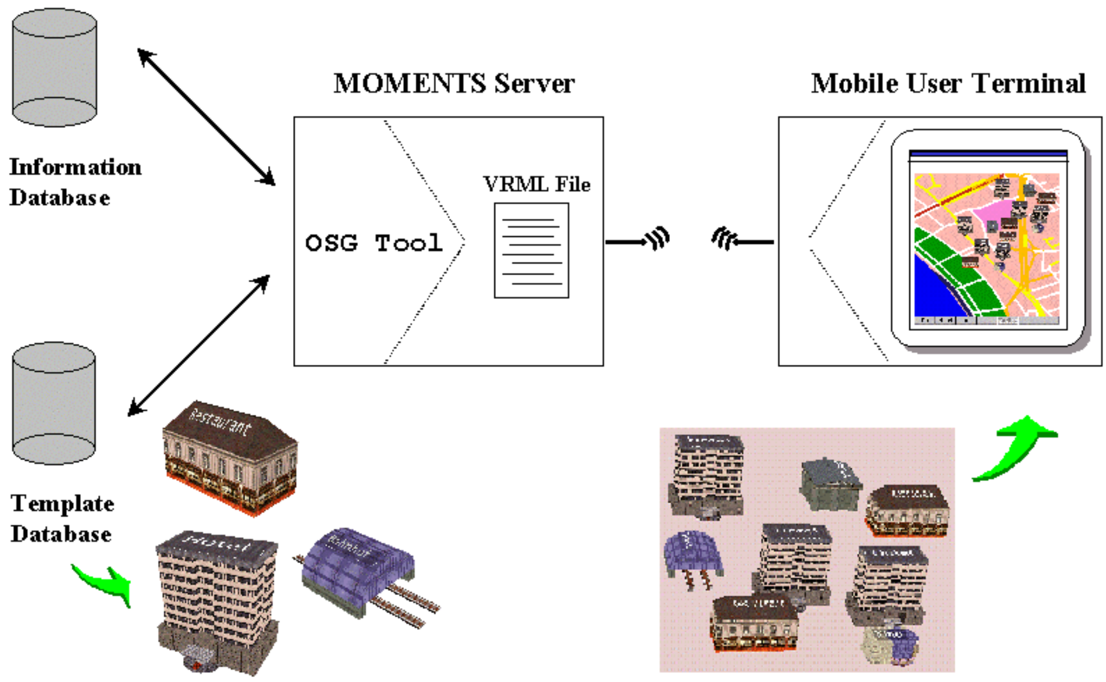

Figure 3.2: On-line generation and presentation of a 3D-object layer.

One could also propose that a service subscriber have the template files for all the service-relevant object categories pre-loaded in his mobile terminal; then, the generation of the VRML file could be executed locally (in the client terminal). Thus, an even lower level of data traffic over the wireless link would be achieved.

OSG System Main Features

The OSG tool has been implemented as a Dynamic Link Library and also as a command line program. The list of input parameters for the internal scene generation includes, among others: (I) the name of a database-input file containing the object specifications for a particular map tile; (II) the name of the resulting VRML scene; and (III) the XY values of both corners of the map tile containing these objects. These XY co-ordinates were planar Universal Transverse Mercator (UTM) or British National Grid (BNG) co-ordinates.

This database-input file is primarily a list of the objects of interest that shall form the layer of 3D objects to be laid over the respective map tile. Each reference to an object is accompanied by the specification of a favoured VRML-based template file for the graphical representation and the information to be assigned to the parameter holders in this template. An example of an object specification in a database input file is presented below; it refers to a ‘hotel’ object category.

```
obj_type "hotel"
my_tmplt_file = "tplt_hotel.m3d"
my_name = "Hotel La Casa Uno"
my_position = 34295451 570428165 0.24
my_scale = 0.004 0.004 0.004
my_rotation = 1 0 0 -.7
anchor_url = "http://www.igd.fhg.de/www/moments.html"
anchor_prm = "target=frame_1"
```

Regarding the VRML scene to be built, each of the compounding 3D objects is an individual information entity. However, the graphical description and behaviour of each of these objects, unless counter required, shall be equal to all of those objects from the same information ‘category’ (e.g., hotels). Thus, several template files were created to individually represent the object categories possibly listed in a database-input file. For a further provision of a VRML object description file to be used as a template file, several recommendations were formulated for the purpose of having files of the most minimal size. These recommendations indicate, for example: the use of geometry primitives to define shapes when building an object (if the authoring tool exports the primitives as IndexedFaceSet, then at least the number of vertices should be reduced), or the file format for image texture files in order to apply effective compression.

Taking into consideration that, at the end, the final VRML scene might be composed of several repeating object structures (e.g., for hotels), the OSG tool uses special node elements when creating the scene, which avoids the repetition of object description. Therefore, a general template file, whose object description just makes a reference to a node previously defined, has been conceived to substitute a template file requested more than once. This method results in an expressive reduction in file size, with the percentage increasing depending on the number of similar objects.

In the end, a compact file will not only by-pass any problems with limited transmission bandwidth, but will also contribute to a quick handling of the file by the M3D plug-in on the client site.

A Template File

In the process of creating a template file for an object category, first, an appropriated authoring tool is used to create a VRML file for the graphical representation of this object, following the recommendations for building a template. This object description is then modified in a sequence as described in the following bulleted items with a standard text editor:

- the original VRML heading information is removed;

- the introductory section of pre-defined enclosing nodes–prologue–is added;
- the file-paths at the 'url sources' (for the texture files) are rectified; and
- the closing section of the enclosing nodes–epilogue–is added.

The template file for the 'hotel' object specification previously presented is detailed below. It is abridged at the object description part for the conciseness of documentation. The 'rule names', enclosed by dollar signs and shown in bold fonts at the introductory section, are the parameter holders that will be translated by the converter to the attribute values stated in the database input file.

```
# >>1   Beginning of the prologue  (with the parameter holders presented in bold fonts)

Group {
 children
  Transform {
   $my_position$
   $my_scale$
   $my_rotation$

   children
    Anchor {
     url $anchor_url$
     parameter $anchor_prm$

   children
    DEF $repeat_tmplt$ Transform {

   children [
# >>1   End of the prologue
# >>2   Begin of the original object description

Transform {
 translation 0.6219 31.699 -44.834
 rotation 0 0.70711 0.70711 -3.1416
 scale 1 0.64935 1

 children [
  Shape {
   appearance Appearance {
    material Material {
     diffuseColor 0.54902 0.48235 0.4
     specularColor 0.9 0.9 0.9
     shininess 0.4
     transparency 0
    }
    texture ImageTexture {
     url "maps/hotel/Steine14.gif"
    }
   textureTransform TextureTransform {
    scale 1.5 2
   }
  }
  geometry
```

```
    . . . }

# 2<<    End of the original object description
# 1<<   Begin of the epilogue

       ] #children
      } #Transform
    } #Anchor
  } #Transform
} # ObjScene Group
# 1<<   End of the epilogue
```

This example of a template file presents an object description that is encapsulated by the minimum and obligatory nodes, which allow for the later integration of the object in a mother scene. Basically, these nodes concern the definition and position of the object in the scene. Other examples of template files have been documented, whose pre-defined encapsulating nodes allow one to provide a response to user interactions on the object.

The Resulting VRML File for an Object Layer

On calling the OSG program file with the correct input parameters, a VRML 2.0 file is generated with the 3D information objects to be presented later over a map tile in a unique scene. An example of a VRML file is presented below; it is presented abridged at the object description parts for the conciseness of documentation. The template used and presented in bold font helps to identify the category of the information object. Please note that for objects, which have the same description (i.e., the same template specification–`tplt_hotel2`–at the database input file), the general template with the VRML syntax element 'USE' has been used in order to reduce the size of the overall VRML scene file.

File **tile0108.m3d** :

#VRML V2.0 utf8

Group { children Transform { translation 0.898045 0.411893 0.24 scale 0.004 0.004 0.004 rotation 1 0 0 -.7 children Anchor { url "" children DEF **tplt_rest** Transform { children [Transform { translation 0.42796 0 20.116 rotation -1 0 0 -1.5708 scale 1 0.4 10.83 children [Shape { appearance Appearance { material Material { diffuseColor 1 0.84706 0.88235 specularColor 1 0.84706 0.88235 shininess 0.57 transparency 0 } texture ImageTexture { url "maps/rest/restaurant_tile3.jpg" } textureTransform TextureTransform { scale 5 1 } } geometry . . .

Group { children Transform { translation 0.697343 -0.407086 0.24 scale 0.004 0.004 0.004 rotation 1 0 0 -.7 children Anchor { url "http://www.igd.fhg.de/~lsantos/#address" children DEF **tplt_hotel2** Transform { children [Transform { translation 0.6219 31.699 -44.834 rotation 0 0.70711 0.70711 -3.1416 scale 1 0.64935 1 children [Shape { appearance Appearance { material Material { diffuseColor 0.54902 0.48235 0.4 specularColor 0.9 0.9 0.9 shininess 0.4 transparency 0 } texture ImageTexture { url "maps/hotel/Steine14.png" } textureTransform TextureTransform { scale 1.5 2 } } geometry . . .

Group { children Transform { translation -0.225954 -0.186443 0.24 scale 0.004 0.004 0.004 rotation 1 0 0 -.7 children Anchor { url "http://www.igd.fhg.de/~lsantos/#address" parameter "" children **USE tplt_hotel2** } } }

Group { children Transform { translation 0.205572 0.727096 0.24 scale 0.003 0.003 0.003 rotation 1 0 0 -.7 children Anchor { url "" children DEF **tplt_theatre** Transform { children [Transform { translation -44.968 -48.685 1.0828 rotation -0.57735 0.57735 0.57735 -2.0944 scale 1.39 5.082 1.39 children [Shape { appearance Appearance { material Material { diffuseColor 0.71373 0.59216

0.49412 specularColor 0.9 0.9 0.9 shininess 0.4 transparency 0 } texture ImageTexture { url "maps/temple/column.jpg" } textureTransform TextureTransform { scale 1 1 } } geometry . . .

Group { children Transform { translation 0.436396 -0.848923 0.24 scale 0.003 0.003 0.003 rotation 1 0 0 -.7 children Anchor { url "" children DEF tplt_kino Transform { children [Transform { translation 30.171 -12.894 32.769 rotation -1 0 0 -1.5708 scale 0.93651 1.3452 1.0611 children [Shape { appearance Appearance { material Material { diffuseColor 0.4 0.7 0.4 specularColor 0.9 0.9 0.9 shininess 0.4 transparency 0 } texture ImageTexture { url "maps/kino/Kino3_tile.jpg" } textureTransform TextureTransform { scale 8 4 } } geometry . . .] } } }}

3.2.4 Generic tools for data optimisation

Another set of tools has been developed for off-line and on-line optimisation of graphical content in terms of the respective file size. The tools are not service-specific and may also be used in conjunction with any of the tools presented in the previous sections.

Code Optimiser

For the project MOMENTS, VRML clear-text (ASCII) encoding was identified as a very suitable format for scene authoring and code manipulation. However, the size of the resulting file for an ordinary basic scene was not adequate for transmission and rapid access over a limited bandwidth. Furthermore, existing VRML authoring tools did not regard the size of their output files; to improve the readability of the content, the output files were generated with much irrelevant and redundant information.

In order to reduce the size of VRML scene files, and, consequently, to decrease the transmission time, a software tool–"VRML Optimiser"–was created. This tool is able to identify and remove irrelevant data from a VRML source file, for example: some white spaces and control characters, comments, and superfluous digits in decimal representations.

The achieved reduction in file size is quite significant, yielding in some cases to an effective bandwidth increase up to one hundred percent. In addition, a notable benefit of this operation is that it does not convey any additional decoding processes for the parser on the client side.

Compression and Decompression of Data Streams

A usual procedure for reducing an amount of data for storage and transmission is the application of a data compression mechanism. However, the benefits of applying such a procedure on data streams depend upon the particular type of data, the original amount of data, and the time needed for the de/compression action.

The development of an intelligent procedure for the decision was postponed, but the following tools, equally necessary, have been developed. These tools are applicable with more efficiency to ASCII encoded files:

- a procedure for the message manager of the client plug-in, which provides identification and reading of a compressed data stream, and decompression in a progressive manner;
- a loss-less compression tool that can be used either on-line during content delivery, or off-line for saving storage space. The tool achieves a high compression ratio of vector graphics data by using a variation of the compression algorithm LZ77 introduced by Lempel and Ziv [Ziv77] with pre-defined dictionaries to enhance content-dependent compression;
- a tool for the generation of pre-defined dictionaries for different data stream types (for instance, CGM, VRML 1.0, and VRML 2.0). These were created with the

Cygnus Developer's Kit (released May 7, 1997; ftp://ftp.cygnus.com/pub/gnu-win32/latest).

As an example of achievements, Table 3.1 shows the size of a VRML 1.0 content file after applying the following optimisation procedures: (I) VRML Optimiser tool; (II) compression with standard "GZIP" algorithm; (III) compression with the use of a pre-defined dictionary; and (IV) combinations of the above.

Compression Procedures	*Size of the file (Bytes)* File 1	File 2
Original VRML ascii file	100.799	73.307
After VRML Optimiser	70.601	36.482
After standard gzip compression.	24.691	14.691
After VRML Optimiser plus standard gzip compression.	22.058	12.779
After enhanced compression with pre-defined dictionary	24.610	14.933
After VRML Optimiser plus compression with pre-def. dictionary	21.911	12.731

Tab. 3.1: Test results from optimisation procedures over a VRML file for reducing size.

3.3 Partial Conclusions

In this chapter, simple but usually despised concerns and practices towards the "raw material" of a service have been advocated and their importance for mobile applications reinforced. For a service-content or user-interface designer, these media studies might be not appreciated or out-of-scope, but for a service provider willing to attend to the needs of mobile users, the author ventures to express his conviction of the high value of such studies and that they deserve more consideration. Thus, for this provider, innovative approaches have then been examined pursuing means for an effective provisioning and handling of visual contents on a wireless platform.

Taking the requirements of services within the project MOMENTS, several software tools have been conceived and implemented for both the content and service provider in order to optimise and tailor service contents for mobile users (i.e., for their distribution over wireless links). Correspondingly, an innovative multimedia presentation tool–a Web browser plug-in–has been implemented for the service consumer's side. It supports the granularity idea for media content in order to save bandwidth, and is able to combine graphical components of different formats in a unique scene graph, which simplifies processing procedures and also contributes to saving resources from the mobile terminal. As a whole, these tools grant the service providers the ability to still offer "rich but not overweight" media contents to resource-constrained mobile users.

There is a fertile market for services to be accessed by users in transit or during field activities. The results of this work have yielded evidence that if adaptations of existing desk-bound applications or new services are to succeed, significant work must also be invested in tools and procedures that act behind a charming user interface.

Further investigations by the author raise the argument that resource availability is a dynamic issue, and to presume its homogeneity among service users is a too simplistic assumption. Therefore, adaptability of the service content to the processing and networking conditions is a functionality to be closely examined. In addition, without the mentioned restrictions concerning caching copyrighted service material, emphasis should also be placed on the media handling mechanism for disconnected operations. For users should be able to collect contents of interest in advance (in preparation for an outdoor activity), and or continue working with them in case of in/voluntary network disconnection. These investigations are described in the succeeding chapters of this research.

Chapter 4: User and Task Analysis Framework

In this chapter, a framework for the analysis of user and application requirements is presented. It has been conceived to support the design of adaptive systems involving mobile actors and components, and with the primary goal of allowing a positive matching of the relevant technology with the practical circumstances of work. Requirements are garnered from a selected context and are used to construct a framework for a better analysis and reasoning process, from which more comprehensive advise can be delivered to a subsequent system function specification process. The requirements are an extension of facts and work presented in Chapters 2 and 3, but here they help to create and populate the design framework, which will be employed in a prototype realisation.

The purpose of having the requirements of a selected context, plus their variances and occurrences, is not necessarily for the development of an application system precisely tailored to this usage context, but primarily to have a better insight into the eventualities and so, to prepare for the development of procedures for system adaptation.

4.1 Introduction

To introduce this chapter, the author would like to quote a statement by Chari and Forster, which appeared in [Chari99], concerning the development of application systems with Augmented Reality and Mobile Computing. "For a successful endeavour with mobile computing, the goal, both in hardware and in software, has to be to create a system that complements a real-world task without encumbering movement. In hardware, this means ergonomic design and component miniaturisation so that the input, output, and processing units do not intrude upon movement. In software, this begets the need for applications with minimal active user input and an output that does not demand constant attention. The successful system requires a balance between these criteria and utility of the final application."

Though specific technology and an area of application are referenced, the author agrees that in essence these remarks are universal and emphasises the need for a stronger human-centred concern in the development process of interactive application systems for supporting mobile activities. Furthermore, figuratively speaking, miniaturisation of hardware should not imply the need to start binding the fingers of our infants to prepare them to use mini keyboards in the future. In addition, echoing trumpeted constraints from the networking area, "the real bandwidth problem is inside user's head!"

4.2 Motivation

The motivation for this investigation concerning user and task issues in system design is to reveal usage models more accurately, and in doing so, to be able to create systems with more resonance for real-world circumstances. Thus, the investigation helps to define how relevant technologies can be exploited to effectively support the user and work activity. By doing this, there is a better chance of any system fully delivering the promised benefits.

Looking back at how technology influenced working practices, Hollnagel and Cacciabue in [Hollnagel99] comment that, initially, machines and tools were designed to facilitate work as substitutes of human functions or as amplifiers, first of human physical strength and precision, then of perception. Afterwards, when the respective demands on the operator, such as sustained attention or the amount of information to be processed, exceeded human capacity, tools for automatic control emerged. It was as a support for this mental work and later, as an amplifier of human cognition that computers gained their respective place. More recently, with computers being able to accompany users anywhere and sometimes even being embedded in the physical surrounds, the set "human, computer, and application system(s)" can be merged into a joint functional feature of several work practices.

This investigative effort is justified on the basis that traditional assumptions built into the design of application systems are either not applicable or have shortcomings in respect to application cases involving mobility and where the computer operation is not the user's main activity and focus of attention. Besides conceptual differences in Human-Computer Interaction (HCI or CHI) observed within the mobile context, considerations towards that functional feature as a joint functioning system (for instance, its behaviour, mutual dependencies, and distribution of tasks among the parts) have been either minimal or are still crude. The context here comprises the computational infrastructure, the application domain, the organisation of the work setting, and the physical environment. In the case of a computer-mediated collaborative work, social factors and group work constraints are also important components of this context.

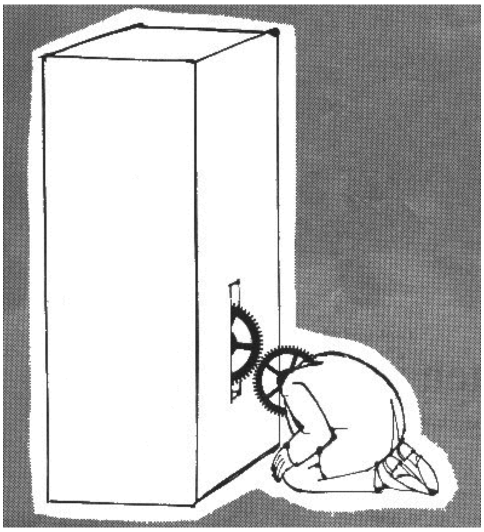

Figure 4.1: Compelled Adjustments.

(From Frankfurt Rundschau, Page ZB 2, 25 March 1995, Author: Jules Stauber)

From a newspaper article, which talked about "searching for identity" (and the imposition of this condition onto human beings in collective or national forms), the drawing above (Figure 4.1) also illustrates a great source for motivation. Subjectively, it conveys the view that some technology innovations viciously force a behavioural adjustment on the part of the user to their own will, and for that, they count on the fact that users might be strictly dependent on them in order to not be excluded, and for going on with their duties or life.

Nevertheless, this conduct is reprehensible and the efficacy of imposing such a method is questionable. In order to increase participation in 'knowledge work' and make technology more accessible to people marginalized by a digital divide, a more lasting system solution has to concentrate on adjustments of the interface man-machine at the discretion of the human agents.

4.3 Background for Requirement Analysis and System Specification

Requirement analysis is that step in a system development process when the purpose of a system and the functions expected from it are assessed and closely examined. In ordinary processes, this endeavour would primarily focus upon key elements and actions that were to be supported or automatically performed by the information-processing systems. However, in more recent times, accounts related to its usability and respective human factor and physical environment have gained a new importance in the design process.

Initially, the goal was to take measures concerning a better Human-Computer interface in order to improve user performance in relation to tools of ever-increasing complexity and finally, to improve consumer acceptance. The most significant contributions to this scene came from theories developed in cognitive psychology, addressing subjects like memory, attention, perception, and mental models[8], aiming to explain the way users behave and interact with technology. Later on, with additional concerns for social relationships and emerging technologies for collaborative work, it was recognised that there was a need to factor in the HCI, social and organisational factors, plus the context into which the systems were to be placed. It was a "turn to the social", as Rogers referred to it in [Roger00] with an emphasis on the informal aspects of work, with contributions coming from other backgrounds like those of sociologists and anthropologists. So, approaches such as Ecological Psychology, Activity Theory, Situated Action, Ethnomethodology, and Distributed Cognition, have achieved prominence in recent years within the fields of HCI and CSCW by presenting new frameworks of analysis, theories, and ideas as complements to the formal methods and models of system design.

Nevertheless, as Shapiro stated in [Shapiro94], when designers "open the box" of social sciences, they find their prospective partners locked in desperate struggles with one other, both between disciplines and within them. Each approach is inclined to regard itself as generating a "core" account of the activity, with the others handling some specialised details or aspects.

This exact situation has been experienced by the author. At first, the author was very content to find an entire, rich research background regarding the set human-machine-task-environment as conditional subjects. However, successively, those conflicts between approaches and theories were confirmed; actually, it was difficult to ascertain the difference between the 'competing' arguments. In addition, in the place of clear guidelines for the methods and processes of the various groups, there was much reciprocal criticism (even with coarse words) and only a few reports on practical examples.

Furthermore, while providing this pluralism of disciplines for a healthy forum, language and cultural differences definitely exist. This makes it very difficult to find the ideas articulated in the same conceptual space, especially to translate the social and psychological findings into a more digestible form that does not require a designer to be sufficiently well versed in a certain theory to be able to read its respective accounts. Moreover, there are clear differences in terms of abstraction, and level and detail of coverage between accounts for the purposes of social sciences, and accounts for the purposes of design. As compared by Hughes et al. in [HughesEtAl98], for the social scientist, the concern consists in capturing and portraying adequately and accurately the ways of social settings, and the activities that occur within them. Whilst for a designer, his task is a decision-making exercise, concerned more with solving practical problems in a constrained arena and in a range of dimensions (functionality, time, cost, etc.), within which, some set of compromises must be worked out.

In conclusion, there are several approaches for requirement analysis and several others ought to arrive due to the transformational nature of technology and work settings. Also, each of the

[8] Taking the definition presented in a literature reference [Dix01] repeatedly cited in this work, 'mental models' are theories that people build to understand the causal behaviour of a situation or the system being dealt with. Concerning this latter, 'human-errors' may occur if the actual operation (inherent in the design or installation of the human interface) differs from the induced, formed mental model.

approaches are worthy of further study in their own right, and, undoubtedly, it is impossible to dispute the importance of studying a usage model and practice prior to the introduction of supporting technology and the subsequent effects. As Graham and Dourish state in [Graham96], technology often fails to support the work it is designed for, or does not allow people to actually engage in their work, because the technology is not aligned to the practices through which they organise their actions, interactions, and work.

Thus, the author, not necessarily following an existing analysis method, agreed to subject accounts related to that 'social perspective' to close scrutiny, and so, to emphasise user and system requirements as they exist in the circumstances of the working practice. As for the purpose, this reflects the (author's) concerns for developing human-centred systems (see several positions underlining this concept in [Talbert97]), especially with regards to mobile applications, where HCI is strongly affected by the context, and where numerous variances and occurrences of particular requirements have to be considered. A framework for user and task requirement analysis was created based on self-established principles and criteria after intensive observations and field studies. A noteworthy literature reference, which gives valuable orientations on critical factors to be observed during such empirical studies is provided by Hackos and Redish in [Hackos98].

The activity target for the computer support has been chosen as the first subject in the analysis, because it orders the involved agents and operational arrangements (infrastructure, system, and physical context) to its own requirements.

4.4 Thinking about the Activity to be Supported

To support the reasoning process, an industrial activity (an extension to the motivating activity presented in section 2.1) is presented in the following paragraph; it is made up of hypothetical circumstances, but is highly probable in practise. The scenario described has been explored by the author in [ASantos99], and recently, this activity has become one of the most popular example application case for Wearable Computers and Augmented Reality technology within the research community and highly advertised by the equipment vendors.

> In modern factory plants, the relevant technological knowledge to be mastered by the workers changes and increases in volume very quickly. This knowledge is required for the manipulation of complex machines, as well as to control and repair them, and to understand implications within the production process. Relevant documentation is similarly increasing, which makes it difficult to keep them updated and, later, for the worker, to find the required information and answers. Another aspect of modern scenarios is the geographical distribution of the agents involved in an industrial process, who still have to remain integrated.
>
> When a service technician goes for a **field activity in a factory plant** (such as maintenance, inspection, or troubleshooting), usually he briefs himself by collecting and verifying the working tools and **documentation** (printed materials such as diagrams, manuals, blueprints) that he knows would be **necessary to have on-hand**. If this person is an **experienced technician** doing a routine activity, he will know what is sufficient to take with him. However, if this person is still **in a training stage** or is a **novice technician**, and the activity includes confrontation with **unpredictable occurrences** (such as fault diagnosis or accident management), this person will **feel more confident** and the task would be performed at maximum efficiency, if the technician **had a nearby means of accessing pertinent information not collected beforehand and of getting assistance from a professional expert**. This expert would

be located in an engineering office ready to collaborate through an information and network platform of the current highest performance values.

Considering the nomadic or roaming technician, the idea to include a **portable and cable-free networked computer** plus a **video camera** and **audio devices** in his toolbox would be an approach with great prospects. Also, with the appropriate **application systems**, when facing **a particularly tricky problem,** the worker would be able to **access instruction manuals**, and **he could beam live images to an expert peer who could then advise him of corrective measures with much more certainty.** The nomadic worker would also have the possibility of **recording circumstances and decision-making** steps during the course of his activity.

Nevertheless, anticipating any ulterior motivation for applying fashionable technologies, one has to remember that the **manipulation of a computer is not the main task** of this worker, who is already under sufficient **physical and cognitive** (e.g., time, safety, responsibility) **pressures** related to this task. Moreover, the **work settings** (e.g., high or low temperatures, greasy surfaces, noise, extreme lighting conditions, a changeable or difficult body position, plus occasional wearing of safety pieces, such as gloves or hard-hats) are quite **hostile to the standard paradigm of desktop computer usage and focused interaction**. Finally, the computer and support system are supporting apparatus, which above all **has to suit personal preferences and abilities, and the criteria of functionality** that the worker would apply when selecting the working tools for his main task.

Hence, there are important ergonomic issues that have to be considered before prescribing a technological apparatus to support an activity without risking it losing its appeal when implemented in the field. Some identified requirements and circumstances, peculiar to the mobile part of the collaborative activity, have already been highlighted (set in bold font) along with the description of the activity; others, not so explicit (but weighted up from these requirements) are described in the following:

1. The physical and cognitive demands for the interaction with the computer and the application system interface should not be obtrusive to the actions and senses that the user would be employing in his main activity;
2. The mobile worker should not be overloaded with the need to care for the operational states of the tool (for instance, hardware and network) throughout the course of his work;
3. The tool (hardware and software) should be able to identify, cope with, and possibly abate detrimental effects of the general and variable conditions of the environment (e.g., lighting, noise, temperature, or confined space); also, the hardware should be able to endure a typical duration of the working activity (with regards to battery charge);
4. Different tasks require different tools; and
5. The mode of work (individual or co-operative, intermittent or continuous activity) should guide interaction and properties of the system tool.

This list of requirements can be extensively increased after a detailed field investigation of the mobile activity. However, this endeavour is far from being simple or a comprehensive account. That is because, besides the variety of usage models, each identified issue may pronounce itself differently for each worker and for each action.

As a first brick in building the analysis framework, a questionnaire has been prepared for this field investigation, i.e., to support assessing operational and physical facts of the activity and requirements of the usage model (not necessarily functional requirements). The questionnaire is not structured in a formal format (i.e., with technical labels identifying analysis theme and sections), because the population to be assessed should respond without any questionnaire-induced predispositions.

This questionnaire is presented in the following segment as Document 4.1. Actually, this document is a specialised version of the questionnaire, subject to translations and refinements according to the context to be analysed. These translations refer not only to the national language, but also to the use of task-domain idioms and vocabularies that were more familiar to the workers and their cultural environment, and to the items and facts, which were pertinent to the actions involved (these were distinguished after a first meeting with the relevant people).

Interviewer: …………………. ……………..…, …./…./…….

At the Company: …………………………………………….

Work Task

Nature and goal of the task:

……………………………………………………..……………………...…………

………………………………………………………………………..……………………

Work place:

……………………………………………...…………………………………

………………………………………………………………….…………………….

Frequency of realisation:

……………………………………………..……………………………………

……………………………………………..……………………………………….

Necessary expertise (Reason: complexity? decisions involved? responsibility?)

- Work experience: ..……………..….………………………………...………
- Education: ……….………..…….……………………………...………
- Task Knowledge (training, coursework): .………………………………..
- Linguistic ability (relevant languages): …………………………………..
- Other (Please specify): ……..……………..………………………..…………
  …………………………………………………………………………………...

Is the activity performed in a group or individually?

………………………..……………………………………………...…………

……………………..………………………………………..…...………………

Requires briefing, planning?

………………………………………………………………………..…..…………

……………………………………….………………………….……………

Is there any execution control-plan or checklist to be followed?

………………………………………………………………………..…..…………

……………………………………………….……………….……………………….

What kind of supporting material (tools, manual) does the worker have to take with him?
…………………………………………………………………………….……………
………………………………………..…………………………………………

Environmental and cognitive conditions at the working place:

- Noisy level: ………………..…………………..……………………….…...
- Lightning level: ..……………………………...……………….…………
- Dust: ..……………………………………………..…………………….
- Grease: ………………………………………….……..……………………
- Temperature: …………………(bearable?….…. , or is it disturbing? ……...)

  Highest …………………… Lowest: ……………………..
- Body position during work (sitting? standing? on a ladder?):

  ..……………………………………………………………………………

  Manual dexterity (hands on hand-rails, hands free?):

  ..……………………………………………………………………………
- Safety (conditions and awareness):

  ……………………………………………………...…………….……………

  …………………………………………………………………………..….…
- Time constraints:

  .…………………………………………...…………………………………

  ……………….………………………………………..……………….………
- Other (please clarify):

  ………………………………….………………………………….………

  …………….………………………………….……………………….………

What are the safety-measures that have to be observed by the worker?
……………………………………………………………………………
……………………..…………………………….…………………………….

At the end of a task, does it have to be documented? If yes, with text? with pictures?
……………………………………………………………………………
……………………...……………………………………………………..

Other comments:

Questionnaire filled out by Ms./Mr. …………………………….

Thank you for your contribution!

Questionnaire: Working Task Fraunhofer-IGD

Document 4.1: Questionnaire for assessing operational and contextual details within an activity.

The appeal of this empirical approach is being able to quickly and directly assess the users' activities and their working environments, and thereby pinpointing constraints and potential problems at further system specification.

The next "subject" in the analysis concerns the role and performance of the human actors within the activity. These actors shall be the prospective users (and judges) of the supporting technology to be specified; hence, their behaviours, level of dependency, and familiarity with the technology are essential considerations for fair results.

4.5 Thinking about the Actors and Users of the Technology

In the course of a working practice, the human actor's performance and conduct is not easily predictable and possible to be modelled. Considering a physical activity, each person has his own pace and abilities, and is affected differently by the environment, his achievable level of dexterity, unforeseen occurrences, and cognitive pressures (and why not, his age). In practices involving great cognitive activity (such as reasoning over the causes of a problem), apart from the different domain knowledge, internal factors, such as motivation or fatigue, or external ones, such as time-constraints or disruptive noise, can provoke substantial changes in a person's performance. Now, let us consider that this same person would have to interact with an additional assortment of technological artefacts (for instance, a computer and an application system) during his working duties; the overall workload becomes greater and makes actions more complex in terms of sensory-motor co-ordination.

Thus, it is straightforward to conclude that **awareness** as to the user's condition and satisfaction should be of particular relevance when prescribing these artefacts, given that they are primarily intended to support him and not to restrain his attention and actions.

In a person-to-person relationship, frustrations are conveyed even indirectly, and adjustments would occur during the interaction. The digital world is still not able to offer this kind of social perception and response (see research efforts in the area of Affective Computing), nevertheless, application systems and interfaces could be conceived **sensitive** to pre-defined constraints, and **adaptable** according to resources and specified user preferences. Certainly, hours spent with an inadequate interaction mechanism (either in hardware or software form), can prejudice the user's opinion of whole computational support and can detract from the job enrichment promised by the system, and–most seriously–the distress and misinterpretations may lead to an accident on the job.

In the hypothetical scenario described in the previous section, there are two types of actors working together on a collaborative task. The first is a technician whose knowledge of the domain and task execution could be average or low depending on training (let us as assume this technician to be of medium ability and aptitude). The second is a professional expert who possesses considerable domain expertise and is skilled in the task execution, as well as in computer operation. Besides individual differences (including gender), there are also social and organisational factors involved in and dictating the collaboration.

Proceeding with the analysis framework, a second questionnaire has been prepared for assessing the human actor. This is presented in the following segment as Document 4.2. As for the first questionnaire in Section 4.4, the version presented here is already in a context-specialised form, dedicated to the mobile worker, and subject to translations and refinements according to the "world" to be analysed.

Interviewer: …………………. ………………..., …/…./……

At the Company: …………………………………………….

Worker

Name: …………………..…………………………………..……………………….

(Anonymity will be guaranteed; if you prefer, you do not need to fill in this part)

Age: ………………………………. Gender: ………………………………..

Do you need eye correction during the work? ………………..…
If yes: spectacles? ………. or contact lenses? ……………

Do you have any auditory problem? …………………..…
any colour-vision deficiency? ….….…..…

Are you left- or right-handed? ……………………………

Do you have to use any special clothing? ………….……………………………

During your work, do you have to use:	always	or depending on the task ?
• Work gloves? ………….………………………	[ ]	[ ]
• Hard-hat? …………………………………..…	[ ]	[ ]
• Ear protection? ……………………………………	[ ]	[ ]
• Protective glasses, goggles? …………………………	[ ]	[ ]

- Other: …………………...…………………………………………………

What is your working experience (years)? ………………………………………...

What kind of work activity do you perform (e.g., maintenance, installation, inspection)?
………………………………………………………………………………………

Are those activities routine work? Are unpredictable situations very likely to happen? ……………………………………………………………………………….

Is the work usually indoor or outdoor? ………………………………………

Conditions of: (please indicate levels, and whether it is disturbing or not)

- Noise: ………………………………………………………………….……
- Lighting: ..……………………………………………………………….
- Dust: …………………………………………………………………….
- Grease: ……………………………………………………………...…
- Temperature: ……………………………………………………………..

Highest …………………… Lowest: ……………………..

- Safety conditions: …………………………………………………………….
- Other (please clarify): ……………..……………………………………………
  ………………………………………………………………………………..

Do you need to brief yourself (e.g., collect tools or manuals, talk to people) before going to perform a work activity?
…………………………………………………………………………………
…………………………………………………………………………………

What type of supporting material do you normally take with you? (for example: checklist, printed manual, with text or picture)
…………………………………………………………………………………
………………………………………………………………………………...

Do you perform your work activity on your own or together with a workmate?
…………………………………………………………………………………
…………………………………………………………………………………

Is it ever necessary to come back to the office to fetch some missing tool or material, or to ask for support from an expert?
…………………………………………………………………………………
…………………………………………………………………………………

Is there always some "super expert" available to contact for assistance in critical situations?
…………………………………………………………………………………
…………………………………………………………………………………

How long does a usual activity take during a normal working day?
…………………………………………………………………………………

Do you come back to your office after accomplishing each work activity?
…………………………………………………………………………………

Do you need to make a report after the work? If yes, does it have to be with pictures, text, or checkmarks on a checklist?
…………………………………………………………………………………

What is your degree of familiarity with computers?

[ ] never used, [ ] sufficient, [ ] good, [ ] use frequently at work:
…………………………………………………………………………………
…………………………………………………………………………………

Thank you for your contribution!

Questionnaire: Worker Fraunhofer-IGD

Document 4.2: Questionnaire for assessing the human actor of a mobile activity.

Data gathered with these two questionnaires will help with the definition of a usage model for the mobile activity and to understand relationships between factors and variables within a system, prior to any form of system design taking place.

4.6 Reasoning on Requirements

Complementing the analysis framework, a Table for Reasoning on Requirements (TRR) has been conceived to assist in the identification of requirements and in a better understanding of how their conditional dependencies might affect choices and solutions yet to be proposed. It is intended to help the system designers to articulate thoughts and revise intuitions, and to use writing as an interpretative process; afterwards, these data would allow him to attend to the relationships of factors, to study how the computational support shall fit into or might disrupt the target working practice, and to judge possible trade-offs.

A TRR has five main topics (previously mentioned as functional features of a usage model)– **Task**, **Physical Context, Worker** (prospective system user), **Supporting System Tool**, and **Supporting Platform**. Each of these topics lists its main component aspects, and for each of these aspects, the respective affecting factors (here called Prescribers) are pointed out, and, likewise, the affected factors in other topics. Task and Physical Context do not have Prescribers, because they are directive requirements–they are starting and immutable conditions in the analysis. All these topics, components, and their relationships were elicited and continuously revised after intensive readings and personal observation of several application cases (two of them are presented in section 4.7).

After the physical exploration of a certain activity context, this table ought to be populated with data from the questionnaires (Working Task and Worker) filled-out by the domain experts, records of passive observation of users' activities, direct measurements and recordings, and historical data.

A final version of a TRR is presented in the following table (Table 4.1). For illustration and clarification of the terms used, the table has been filled out with data from the activity described in section 4.4, considering the mobile worker as main actor. Please note that **the order of dependencies presented in this illustration denotes the user-centred method central to this work**, for example: Task, Physical Context, and Worker drive the specification of the Supporting System Tool and Supporting Platform; Worker and System Tool co-drives the specification of the Supporting Platform.

Prescriber	T1 - Task	Affects
	1.1 Goal Troubleshooting, Maintenance or Inspection of machinery.	
	1.2 Course of actions involved Plan activity run, analyse problem, consult help material, manipulate working tools, check machine operation, discuss with remote professional expert, record activity.	T4, T5
	1.3 Nature Programmable activity, but with unpredictable occurrences, different modalities and limbs involved. Not involving repetitive motions.	T4
	1.4 Realisation mode	T4, T5

	One person, but temporary or continuous co-operation with a remote peer most probable.	
	1.5 Domain knowledge Requires from the operator reasoning based on domain knowledge.	T4
	1.6 Task knowledge Operation skills required.	T4
	1.7 Location Out-of-office activity, but still indoor (factory floor); Entails mobility of the worker.	T4, T5
	1.8 Physical complexity Hands-on work with many complex manipulations and skilful actions requiring sensory-motor co-ordination.	T3,T4, T5
	1.9 Cognitive complexity Attention and perceptual resources of the worker highly required. As classified by Galliers et al. in [Galliers99] when investigating the occurrence of errors in human actions, "cognitive complexity" is associated with the application of reasoning and knowledge, and rules for problem solving, requiring decision-making, problem solving, and judgement.	T3, T4
	1.10 Duration, time-constraints, interruptions Assumption: one hour, no interruptions.	T3, T5
Prescriber	**T2 - Physical context**	**Affects**
	2.1 Environmental conditions Poor or less controllable lighting conditions, average temperature, greasy machinery and tools and requiring use of work gloves, noisy ambience, uncertain levels of humidity and dust; Machinery with electronic components and controls.	T3,T4, T5
	2.2 Physical access to the supporting tool Uncertain possibility to place the supporting tool for direct reach; Uncertain power-supply and network connection nearby (also called the "last-meter condition").	T1,T4, T5
	2.3 Sources of interference to user actions and system Apparently no mentally disruptive environmental conditions; Potential hazards due to moving parts; No environmental extremes likely to affect computer operation; Sources of interference to the air-interface radio network link.	T3,T4, T5
Prescriber	**T3 - Worker (prospective system user)**	**Affects**
T1	**3.1 Level of qualification for the task** Assumption: workers with medium ability and aptitude, and domain expertise.	T4

T1, T2	**3.2 Temporary and permanent physical impairments** Limited dexterity due to body position, occupied hands, and use of work gloves; hearing prevented by surrounding noise or ear protection; Use of eye-prescription corrections or safety glasses; Use of head protection (hard-hat or sunshade).	T4, T5
T1, T2	**3.3 Focus of attention** Complexity of the task requires concentration; no obtrusions; Senses more affected by or responsive to stimulus from the main task.	T4, T5
T1, T2	**3.4 Other cognitive factors (motivation, time-pressure, fatigue, and safety awareness)** Assumptions: motivated, under time-pressure, confident of the support from the system tool, aware of hazardous potential of the tools.	T4, T5
	3.5 Familiarity with computer technology Assumption: medium ability.	T4, T5
Prescriber	**T4 - Supporting System Tool**	**Affects**
T1, T3	**4.1 Service** Interaction interface for accessing local and remote (graphical) data; Conferencing Tool (sharing of video, audio, static images, overlay of personal annotations and pointing mechanism).	T5
T1,T2, T3	**4.2 Interaction interface design** User Interface with interaction levels and categorised information space; Action sensitive to the context; Setting of the interaction medium; Not involving steep learning curve, enhance motivation and trust in the technology; The user should manage his attention resources;	T5
	4.3 Essentials of system design Concern for heterogeneous platforms and user profiles; Distribution and best-possible utilization of the technical resources and interaction mechanisms; Awareness of the cognitive resources of the users.	
	4.4 Critical resources requirements Availability of interaction devices; Guarantee of network connection for handling large and time-dependent distributed media contents.	
Prescriber	**T5 - Supporting Platform**	**Affects**

T1.2, T4.1	**5.1 Hardware** Computer device with interaction devices, such as keyboard, pointing mechanism, visual display device, microphone, and earphone.	
T1.2, T4.1-.2	**5.2 Other service-oriented networked appliances** Video Camera.	
T1.2.-.4-.7-.8-.10, T2, T3.2-.3-.4-.5	**5.3 Physical characteristics and features** Portable, small-sized, lightweight, cable-free, battery-supplied, durable, ergonomic interaction devices, low-power operation, heat dissipation not harming user; Individual use; Adequate for the user and physical context, Safe use; Aesthetically satisfying.	
T3.3-.5, T4.1-.2	**5.4 Performance and resource values** Resources sufficient for the interactive and time-dependent multimedia services; Enough local storage space for multimedia data; Cope with the drawbacks imposed by the physical context.	
T1.4, T2, T3.4, T4.1	**5.5 Communication network (medium and performance)** Infrastructure for wireless connection: PC Card and base station; Radio signal with bandwidth, coverage, and reliability for the interactive, multimedia, and time-dependent services; controllable interference from physical surrounds.	
T1.1, T3.4, T4.1	**5.6 Link or interference with the surroundings** Radio signal might interfere with electronics in the machinery; Data and privacy at risk of exposure; Current concerns that radio waves may harm people.	

Table 4.1: TRR – a table for reasoning on usage requirements.

While this table does not claim to be comprehensive, as only a selection of aspects has been included and mostly resulting from a heuristic process, it does offer, nevertheless, a formal characterisation of an activity, and provides a tool upon which a comprehensive set of interdependent requirements for consideration can be delivered to a system designer early on in the project. Understanding the usage model will make this designer much better positioned to conceive a system that matches the way people behave and use technology, and to assert the required functionality.

In the following sub-section, the author illustrates the use of the TRR for a precise and oriented specification of the visual display component of a Supporting Platform (Topic T5), assuming that Topics T1, T2, T3, and T4 have already been defined (as the sequence of specifications should be). Nevertheless, in the face of a constraint concerning one of these topics, or a mandatory project decision, such as the reuse of an existing component or expenditure limit, as well as user preference, then one could go in the reverse direction of the affecting factor(s) (Prescriber/s). This provides the basis for the adaptive features of a system and indicates where to promote system adaptations.

4.6.1 Choice of the infrastructure

With the current growth of mobile computing and telephony, both for personal and professional use, there is an enormous variety of new information and communication devices and networking services coming into the market. Pushed by market competition, some paraphernalia is created even without an analysis for demand or clear orientation for an application case and user profile; in common jargon: “throw it in and hope that it sticks” (i.e., release the product and hope that it takes off due to the novelty, fun-of-it, or the upgraded capabilities; the application defines itself later).

For a correct specification and choice of system Supporting Platform, it is essential that the system designer makes his decisions based on comprehensive accounts of the task circumstances and user requirements. These accounts shall prescribe the adequate resources and conditions for realizing the application. An ill-considered choice of device and communication network infrastructure can dramatically affect usability and the value of the system.

The author will illustrate how the TRR–Table 4.1, filled out with data from the activity described in section 4.4, is used for a meticulous specification and characterization of the visual display device.

A new table is created only with the Topic T5. Afterwards, the sub-topics (Prescribers) that “affect” T5 and are related to the display device are listed in this new table. Lastly, going along side each of these “affecting” topics, the Topic T5 is filled out with the requirements they evoke (see Table 4.2).

Prescriber	T5 - Supporting Platform	
	• **Hardware**	
T1.2, T4.1	Visual Display Device	
	• **Other service-oriented appliances**	
	• **Physical characteristics and features**	
T1.4	One-man use (constraint as to sharing the view of an image with an accompanying person or another peer);	
T1.7, T2.2, T3.5	Portable: lightweight, built-in in a portable device, hand-held, headset (hanging around the neck or head-mounted);	
T1.7, T1.10	Low power consumption;	
T1.8, T3.3	Constantly positioned in direct line-of-view, no necessary adjustments;	
T1.10	No physical discomfort caused by use; if device is head-mounted, then lightweight and with bearable heat dissipation;	
T2.1	No touch or pen input screen due to grease on user’s fingers or work gloves;	
T2.2	Hand-held device or headset due to difficulty in finding flat surface to place the device;	
T3.1, T4.1	A device for short interaction periods;	
	If headset, appropriate size and possibility to use simultaneously	

T3.2 T3.3 T3.4	with glasses; Not obtrusive to user's view of task items; if head-mounted, better monocular or see-through display; If headset, no breakable optical element close to the eyes; preferably with no cables (wireless inter-device link); cosmetically pleasing;	
T2.1 T2.3 T3.2 T3.3, T4.2 T3.3, T4.1, T4.2 T3.4, T3.5	• **Performance and resource values** Luminance/Brightness and contrast ratio, and see-through adjustable opacity for variable lighting conditions; Average operational temperature; Horizontal/Vertical viewing angle, readable from any body position; no touch screen; Size sufficient for presenting readable and arousing messages and complete information content; High resolution and number of colours for information fidelity and equivalence to desktop siblings, and for salient message effect; Focus depth adjustable to a similar distance as real-world objects.	
	• **Communication Network**	
	• **Link or Interference with the surroundings**	

Table 4.2: Task- and user-oriented requirement assessment for the display device.

With Table 4.2 on hand, a survey of the market for suitable devices can be more focused and less based on intuition or personal temptations. When examining eligible options, such as the ones shown in Figure 4.2, which were culled from magazine reviews (e.g., www.vrnews.com/issuearchive/vrn1001/vrn1001tech.html) and vendors' Web-sites (e.g., www.hitl.washington.edu/scivw), one is better equipped to weigh the respective pros & cons.

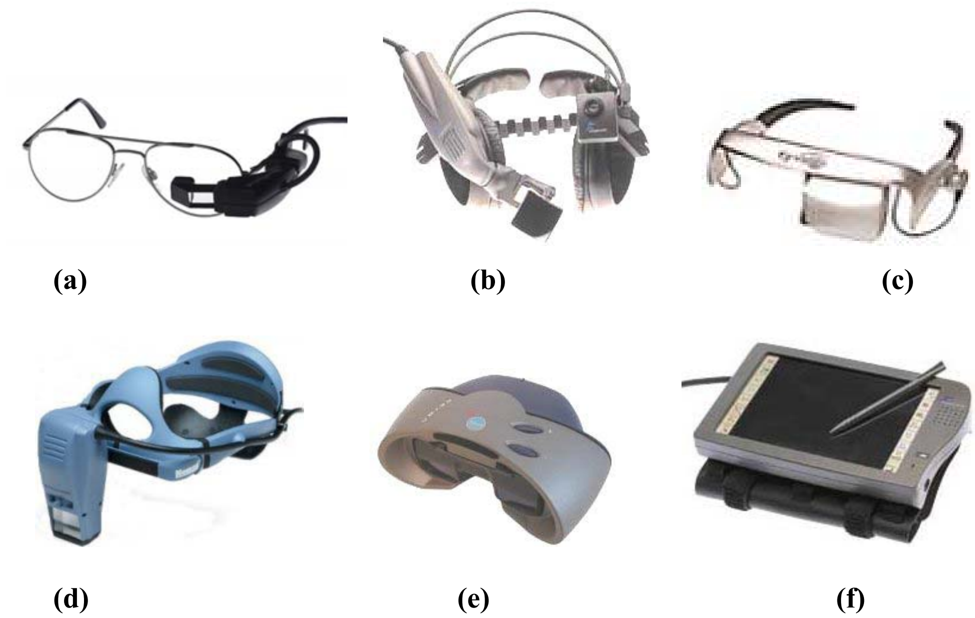

Figure 4.2: Examples of portable visual display devices commercially available.

Afterwards, it would be a question of thinking about priorities, confirming affordability, and, eventually, reconsidering project decisions and trade-offs in system functionality.

4.6.2 Decision and licence for adaptation

From the previous compilation of display devices, the Head-Mounted Display (HMD) shown in 4.2(b) is examined. In particular, this is a good example of a device that possesses most of the required characteristics for use within mobile computing applications. Its head-based feature satisfies ergonomic concerns and can accompany the user's body position and gaze even in contorted postures imposed by certain away-from-the-desk activities. However, realising the real benefits is dependent on a comprehensive analysis according to the application systems and the usage model.

After examining this display device, the author presents the following list of remarks, categorized into pros & cons, to help with the selection and specification of the equipment.

Device xyz	**Pros**	**Cons**
• **Physical characteristics and features**		
Constraint as to sharing the view of an image with an accompanying person;		1
Head-mounted set, as mobile as the user;	1	
Weight of examined model is around 400 grams, also bulky for extended period of utilisation;		2
Monocular, tiny monitor in front of one eye. One would be able to proceed with current activity and access the supporting computer application with a subtle deviation of gaze;	2	
Primarily hands-off operation, position adjustments only at beginning and when temporarily moving the unit away from the eye;	3	
No problems in finding a level and safe surface for placing the device;	4	
Potential obstruction of one's view of the surroundings;		3
There is a minor effect of light reflection and parallax;	5	
Difficult to use with corrective glasses or head protection;		4
Nuisance due to physical discomfort or cosmetic appearance;		5
Apprehension due to proximity of breakable parts to the eyes, and because headset and cables are likely to get entangled with the machinery;		6
Contact may raise hygiene and cleanliness concerns.		7
With see-through lenses, it is possible to superimpose digital information relative to user's view of "real world" items (such as by Augmented Reality technology);	6	
Possible support for the installation of other devices, such as video camera or headphone;	7	
• **Performance and resource values**		
Prevailing low-resolution in comparison with desktop siblings and low-brightness (a temporal development problem and cost factor);		8
Some decrease of interaction media (non touch- or pen-sensitive display);		9
Operational temperature should be between: 0°C and 40°C.	8	
Small text font and graphical icons might not be readable, and crucial information might not be identified;		10

Information conveyed by colour in jeopardy due to prevailing low colour-depth displays (a temporal development problem and cost factor);		11
Some models offer the possibility to adjust focal projection of displayed image. This would improve user's comfort related to a constant change of view focus (from real world items to the display device, and vice-versa);	9	

- **Statements from the manufacturer (**from the official User's Guide**)**

  These statements present instructions for the users to follow, and warnings to be heeded. Usually covering any possible problem, the manufacturer seeks also to safeguard himself from eventual accusations of misinformation; strange that these warnings contradict or are omitted from advertisements concerning the potential use of a portable computer and this HMD as a whole.

  "Some people may experience eye fatigue, nausea, dizziness, light-headedness, disorientation after an extended period of time;

  A small portion of the population might experience epileptic seizures when viewing certain kinds of flashing lights or patterns;

  Never use the HMD when operating a motor vehicle or any other device or machinery that requires both eyes;

  The HMD is tethered via a power cable to the CPU. Do not use the HMD in environments where any part of it might get entangled with other objects, moving parts or machinery;

  DO NOT use the HMD while maintaining or servicing equipment with moving parts, which are exposed and present a hazard;

  Should not be subjected to extreme environment."

- **Price and availability**

At first observation, the scores of pros & cons seem against the employment of HMDs. Furthermore, the eleven 'cons' listed by the author give ground for the following assumptions:

- 2, 3, 4, 5, 6, 7, and 10 might lead to impulsive rejection from the user and might cause accidents;
- 8, 9, and 10 might lead to misinterpretation of the information content; and
- 8, 9, 10, and 11 might lead to deficient information exchange between groupware partners.

Nevertheless, most of the potential problems could be lessened or solved by:

- a stringent selection and trial of the model;
- clarifying benefits to the user, and practising with him;
- implementing an adaptive feature in the system tool for a flexible and best-possible utilisation of the technical resource, and for providing interaction demands that correspond to the cognitive resources of the users and characteristics of the usage model; and
- divulging individual constraints among service partners in the case of a groupware system tool. This helps to structure interaction and improve collaboration.

Considering the increasing variety of display devices in terms of form and performance, plus the fact that intangible user acceptance and price play an important role in the end, the last two proposals listed above contribute to the idea of adaptive systems glowing more intensively. Especially for the Service–Conferencing tool, the clear distinction between the users' platforms and usage models compels the system to behave differently at and for each end-terminal.

4.7 Assessing the Analysis Framework

In order to estimate the value and quality of the analysis framework, its tools have been applied in two different and representative real situations, where mobile computing could be seen as a promising solution to increase the productivity of the field activities. The first situation was an industrial case quite similar to the scenario described in section 4.4, and the second was related to the maintenance and inspection of airplanes.

In both cases, the author made a preliminary visit to the sites in order to gain a first impression of potential working tasks to be supported, the people involved, and the environment. A presentation of a few examples of mobile computer devices and suggestions for potential applications, with pictures and system demonstration, helped to heighten the interest in cooperation, in so far that several problematic situations were soon enthusiastically indicated. In one case, even from the office staff, the presented devices received some criticism straight away regarding the inappropriateness of some of their physical features to the task locations and other circumstances. Notes were taken, and the goal of the analysis was clarified taking these arguments onboard.

In both cases, meeting reports were prepared following a template as shown in Document 4.3.

Meeting Report

Location, Date:

Visited Group: Mr. H. W. (Division Manager) – Tel.
Mr. N. B. (Supervisor Engineer) – Tel.

Participants from IGD: L. S., P. S.

Report prepared by: L. S. Distributed on: / /
Recipients of this report: Mr. H. W., Mr. N. B., Mr. P. S., and Mr. L. S.

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1. Objectives of the Visit
2. Visited Groups and Places
3. Working Activities
4. Expression of Interest in Our Presentation
5. Our Technology and Tools, and Suggested Applications
6. Their Current Problems and Needed Support (Information and Cooperation)
7. Working Environment
8. Current Procedures
9. Expression of Appreciation and Potential Applications of the Presented Tools
10. Potential Users from Their Own Perspectives
11. Comments on Positive Features and Functionality of the Presented Tool

12. Suggestions for Changes and New Features in the Presented Tools		
Conclusions and Action-Points		
Document: .doc	In preparation / in review / **released**	Page 1 of 1

Document 4.3: Meeting Report.

From past working experiences as a system analyst, and conclusions inferred from these case studies, the author presents some noteworthy advice on how to approach prospective application system consumers:

- The target users are the experts in their business. Hence, do not approach them as knowing all about their problems and having the ultimate solution for them.
- Do not present your solution as an incontestable item, otherwise, they will be most hesitant to criticise and suggest modifications.
- Listen carefully to and take note of jargon and the “fine print” of reported cases (sometimes the hilarious details are the most revealing).
- A confidentiality guarantee and anonymity as to data is the way to gain the confidence of the workers, and to ascertain “out-of-sight”, improper use of tools or practices out of prescribed instructions.
- Write a report for each meeting and send it to them to review. People will be most collaborative after seeing that their comments were taken into consideration, and will be much more attentive to correcting misunderstandings.

After obtaining their permission to carry on with the analysis, the course of further procedures was arranged with a relevant population of technical people. In preparation for the analysis of the second case, the two questionnaires were translated to German, and in both cases, some of the questions were adapted in keeping with the reality and idioms of their work domains.

The interviews were carried out, and later, the workers’ activities were observed for a while, and pictures were taken; these documentations helped to complement the data and records from the questionnaires and TRRs. In the following section, the author presents a summary of each scenario and some selected outcomes of the analysis process.

The results and benefits of applying the framework cannot be quantified in figures, but they were very effective and clearly showed their merit in the author’s opinion as a system designer. Several new applications and problems were discovered, and real demands, as well as wrong assumptions, were revealed. For one of the study cases, a new interaction device was even suggested and later designed (a dual keyboard system, with one of the keyboards consisting of only a few keys to be fixed on the detached video camera and to allow one-handed system operation). Finally, the simple expression of interest in the demands and opinions of the real end-users has been highly praised by them and has contributed to making the investigations very engaging, for their participation (such as during the test installation of wireless LANs) and enthusiastic input have greatly contributed to orienting the system design and have saved much development time.

4.7.1 Application scenario 1

Task, Location, and Worker

Troubleshooting and maintenance in the production lines of a shoe design and manufacturing industry.

Within the production process of the case industry, the product design, the fabrication planning and documentation, and personal training occur in the mother plant. Afterwards, the manufacturing work is realized in a factory plant selected from among five of them; these are located from 150km up to 5,000km away.

In a factory plant, the production lines are located in buildings that are usually very large (around 12,000m²) and without office facilities. Inside these buildings, it is relatively noisy (85db), but with good lighting conditions (1,000lux). In addition to the people involved in the manufacturing processes, there are also on-site technicians responsible for maintaining and repairing the machinery, and for checking the product quality during the various stages of the manufacturing process. These technicians are always available and might be called per internal mobile phone system in case of a problem. Despite the grease and grime of the machinery, they always have enough room to move around and to posture themselves close to a machine in safety. See pictures taken in Figure 4.3.

In general, these technicians are well trained to solve any possible problem related to their duties on their own. However, occasionally, there are some critical and unpredictable situations, which–though rare in occurrence–substantially affect operational costs in a final analysis. Some of these critical situations are:

Troubleshooting: occurrence of a problem in the production line during manufacturing operations due to incorrect configuration of a machine or incorrect parameterisations in the process.

In this situation, if the local technician is not able to solve the problem by himself, he needs to ask a colleague from the engineering office for assistance. Currently, either the problem is clarified and worked out orally via mobile phone, or in the case of greater complexity, pictures are taken with a digital camera and later sent as attachments to e-mail from a PC in the technician's office. In the worst-case scenario, a professional expert has to travel from the mother plant to the respective factory plant.

It would be more effective, if the technician could stand 'in front of the problem' with a networked computer, and discuss the problem with his colleague, sharing pictures or video taken of the machine or shoe. Upon the request of the expert, the technician could 'show the problem' from different angles and at different proximities, point out and compare measures, and also be able to implement any suggestions from the remote expert right away. In addition, nobody would have to leave to send an e-mail and to wait for the answer, or to travel to see the problem.

Maintenance or Repair: as a corporate rule, all the tools and printed documents that are related to a certain machine should be located in a small cabinet attached to it. However, it often happens that a maintenance activity is in progress and some material is found to be missing. In this case, the technician has to interrupt his job to look for the appropriated material, which can be a manual with textual guidelines, exploded technical drawings, or updated maintenance records.

Once more, a networked computer would give the worker access to updated material in digital form right at the place of need. Additionally, with a video camera, the technician could also document his maintenance activity and decision making on-line by recording a video sequence together with pertinent annotations. Later, this type of record would also be very useful for preparing digital material for training apprentices (as with Augmented Reality techniques), and for assessing professional knowledge for further process automation.

(a) Complexity: two-handed physical operations.

(b) Variable working positions.

(c) Difficult visual and manual interaction with a computer.

(d) One-man action or with accompanying persons.

Figure 4.3: Workers (potential users) in their task conditions.

The idea of a wearable computer was appreciated for the consequent flexibility and possible manipulation from every position of the worker (see pictures in Figure 4.3).

Inputs for Supporting System Tool and Platform

- For ordinary problems, a mobile technician is well trained to solve them by himself. He would need computer support and remote assistance only in complex cases of incorrect configuration of a machine or incorrect parameterisations in the process.

- In some cases, the technician needs images with enough quality to reveal to his remote colleague "a misplaced stitch with a black thread in black leather" or "an excess of colourless glue on the sole". This should be carefully considered when selecting the video camera and the system procedure to handle and present visual information, and of no lesser importance, a networking setting able to satisfactorily deal with the amount of data produced by such images.

- Due to the great number of machines with electronic components and metallic physical constructions in the building, disturbances in the radio signal network were almost certain to occur. Therefore, a test for a wireless network installation (a "site survey", as mentioned in section 2.3.2) was arranged with a technology reseller to determine the optimum utilization of networking components and to maximize coverage and network performance. The tests showed that with a single access point there were no blind-spots (i.e., full signal coverage inside the buildings), but a significant degradation of the promised bandwidth (from 10Mbps to 2.3Mbps); these values would have to be considered by the system tools.

- Due to the conditions found in the physical environment plus the grease-covered fingers of the technicians, the manipulation of a miniature keyboard or touch screen would be problematic, as would the performance of a voice recognition interaction medium.

- The price and import of a wearable computer would be a problem. However, the user himself favoured (and the physical conditions and operational ergonomics allowed for) the use of a laptop over the traditional handcart used for bringing operational tools.

4.7.2 Application scenario 2

Task, Location, and Worker

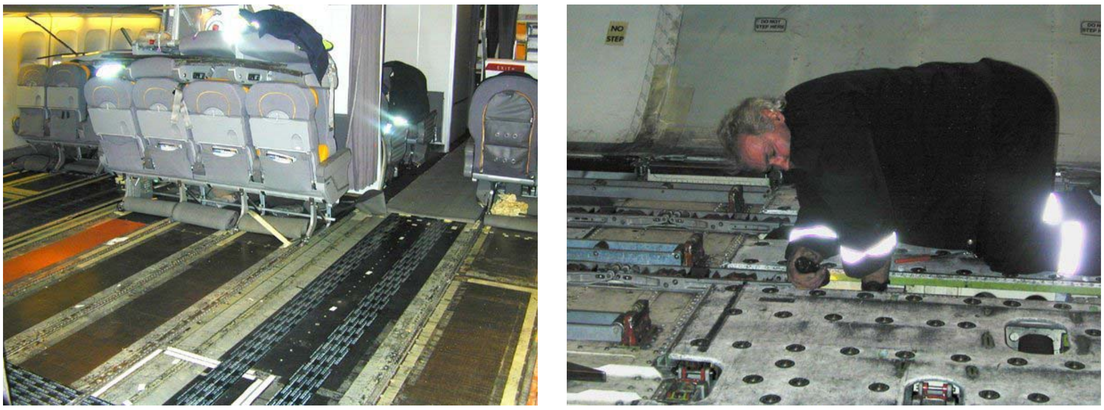
Maintenance of civil aircraft in an airport complex:

A leading airline in Germany has a business branch specializing in technical services for civil aircraft. Its second most significant operational plant (control and maintenance offices) is located 600km south of its headquarters within the premises of an airport. The technical staff at this plant are well prepared to perform all the inspection, maintenance, and repair services needed during an aircraft's life cycle.

Pertinent for this technical work, there is a service office, where all relevant equipment, information services, and printed material can be found. Close by, there is building for repairing detached parts and a very large hangar (around 15,000m²) where the aircraft are parked for the maintenance services. In this hangar, lighting conditions are very variable in terms of: in-door versus out-door (on the runway), inside versus outside the aircraft, work on external parts versus 'inside' the landing-gear box or turbine; similarly variable are the noise conditions, which sometimes reach such extremes that ear protection has to be used. In the case of emergency work taking place directly on the runway, the environmental temperature might surpass the extreme of 0°C in the winter (or 40°C in some other countries during summer). In the hangar, one sees workers performing their tasks while laying on the wings, hanging on a ladder, 'inside a turbine', and stepping up and down to check documents. See pictures in Figure 4.4.

(a) Working conditions: body position, surface for a computer, lighting, use of gloves, etc.

(b) Working conditions: position, safety, restricted mobility, etc.



(c) Need of extra appliances: electric torch, endoscope (or video camera).

(d) Progressive identification of problem, need of reporting with pictures.

(e) Leaving the immediate site to acquire supporting data.

Figure 4.4: Workers (potential users) in their task conditions.

There are regular inspections and preventive maintenance activities when the certified and highly experienced technician theoretically would not need computer support. In this kind of work, taking along a printed checklist with the work plan is compulsory. However, as it was remarked–"Here, some problems repeat themselves, but not like on an assembly line–there is always something new, unexpected, and under different conditions".

Sometimes, critical problems with unknown causes also occur, where the technician would certainly benefit from the possibility to access relevant information (diagrams, control tables, manuals) on-site or to obtain the support from an engineer back in the service office. For example, the pilot of an aircraft "waiting in the wings" announces an abnormal or emergency situation (generally caused by a breakdown); in this situation, there is a great deal of time pressure in terms of handling the appropriate actions, just as with the level of risk and costs. It would be even worse for an aircraft about to land. In both cases, there is no time for the maintenance staff to guess and muster together the correct supporting materials, based on the pilot's explanation, before driving to the runway.

Intercontinental remote maintenance is also a critical situation for which the employment of electronic conferencing systems should be considered. Currently, as remarked, "the quality of problem representation is in general very low"; this means, the problem description is often incomplete and/or incorrect, highly dependent on the knowledge of the local technicians and their subjective opinions. The poor information exchange may cause the remote experts to prescribe sub-optimal or erroneous actions.

Other working tasks with great potential for the employment of a mobile computing support are mentioned in the following text.

Inputs for Supporting System Tool and Platform

- Currently, endoscopes are used to investigate places with difficult access in the aircraft and for which, the removal of obstructions (e.g., seats, carpet, and floor lights, or lavatory fixtures) would be extremely expensive. One person operates the endoscope and an accompanying person observes and records the images on a portable unit. A miniature video camera would be a profitable substitute for the current apparatus. A light source attached to the camera would be needed.

- As one technician remarked during an interview: "A picture is worth a thousand words". Visual presentation and a clear description of a problem (to be transmitted to the remote professional expert) is a must.

- In the case of maintenance activity contracted by a partner airline, pictures showing the problematic area are very important data in documentations, "before" and "after" shots.

- Often, the mechanical or electrical technician has only one hand free to manipulate a tool, since he must use the other to hold onto a handrail. A wearable computer with a head-mounted display is very appropriate and some kind of mini-keyboard or mouse would have to be installed over the detached video camera for further system interactions.

- As suggested by interviewed technicians and engineers upon seeing a short demonstration, a video sequence should be used only for a first impression and to help identify the problematic part. Afterwards, single pictures, taken with a better resolution and focusing on this particular part, are sufficient for discussion and offer a more 'stable' subject from which one could even perform measurements. For the system tool and platform, such a requirement is most welcome, because the consequent data reduction alleviates processing and network-related resources. In case AR functionalities of matching real to digital entities are to be offered by the system, the benefits are even greater.

- Due to the variable lighting conditions, care should be taken when selecting the video camera and with the handling of visual information by the system tools.

- The noise conditions plus the eventual use of ear protection is a potential problem for voice-recognition system tools and audio interaction as a whole.

- The extreme environmental temperatures on the runway are very unpleasant for the worker, and an extended working period or extra workload would be very disturbing. In the cold, his extra clothing might prevent the use and manipulation of a wearable computer, and the operating temperature extremes of the devices to be specified should be taken into consideration.

- The straps and cables of a head-mounted display would be problematic for actions close to or ‘inside a turbine’.

- In the case of intercontinental remote maintenance, the asymmetries between the partners are highly significant. In addition to the support for an information exchange that would ensure the efficiency and safety of all actions, means for a remote awareness of the other partner’s conditions and constraints is very important to structure the interaction. Networking could be a restrictive issue for an on-line teleconference.

- A wireless LAN has been installed and tested for performance and coverage in the maintenance building (a “site survey”). The results were satisfactory, but blind spots were identified inside the aircraft. The installation of extra aerials should be tested. Regarding possible interference in the environment, the airport authorities actually restrict the use of such networks, and an approval is mandatory.

- An interface with the Boeing Aircraft Maintenance Database System should be considered, as with the new onboard satellite connection to be offered in the year 2003 in the model A340-600.

4.8 Partial Conclusions

In this chapter, the author has emphasised how important a human-centred approach is in the specification and development of tools aimed to support mobile activities. This approach implies a consideration and an in-depth analysis of all the entities–human, work task, environment, and technology–involved in the activity, as a cooperative functional set, which has to be in harmony in order to be effective.

The reasons for this concern have been explained, but are important enough to reiterate: miniature and personal devices, such as wearable computers, in addition to the enhanced physical availability, can be said to have achieved the status of an extension of the human body and skills. Intimacy is very high and can positively augment human functions, but at the same time, it can be easily discarded if it obstructs intentions and needs; and humans have different needs in different situations and places. According to a legend, Beethoven was annoyed with his hand as a flipper, and wanted to tear the skin between his thumb and the adjacent finger in order to span farther than a tenth on the piano; certainly, it is much easier to throw a wrist-keyboard away should it impose some sort of handicap on the movements of a worker under time pressure. In addition, being mobile means among other things: divided attention, less controllable environment, workload issues plus interruptions, interferences, etc. Thus, the software tools have to offer the additional working functions, but have to be conceived based on studies of the efficiency of people in their working environment, and the circumstances and eventualities involved.

A framework for an analysis of user and application requirements has been formulated and presented. This framework is meant to help system developers during early design phases to avoid making decisions that might later prove fatal to the usability of the implemented system solution. It comprises two questionnaires, a table for reasoning, a template for a meeting report, and the methods for using them. These tools were successfully applied in two study cases, whose assessed entities and facts enabled the author to demonstrate valuable inferences for a system design. In these cases, one could also perceive the number of situations and variations where this or that solution would be better, not appropriate, or even dangerous.

Afterwards, it is a hard task for a designer to find an intermediate and or universal solution in light of so disparate, divergent, or even conflicting conditions and demands; this can only be achieved by trade-offs between the known entities and facts, and functionalities to be offered. Therefore, a system tool has to be as adaptive as possible in order to respond to most of the requirements and settings, and as open as possible to be able to include the constant technological evolutions and new requirements. In the case of a conference system, the challenge is from the very beginning more complex, because the system has to behave differently for each end-terminal and user.

In addition to the study-cases, this framework has been used within an on-going co-operative project, namely–Model-driven Development of Telecommunication Systems (MDTS), to support the evaluation of the application scenario. More information about this project can be found in the frame below and in the project Web Page.
(URL: //www.fokus.fhg.de/mdts/index.htm).

In the next chapter, the author proceeds with analysis issues related to mobile applications, but in the direction of system functionality and the need for adaptations.

Model-driven Development of Telecommunication Systems

The growing variety of devices and networking infrastructures in an increasingly interconnected world adds substantially to the demand for suitable software solutions in the information and telecommunication technology arena.

The main objectives of the MDTS project are:

- Definition of modelling concepts and development methods for distributed real-time systems with particular attention to quality of service requirements;
- Provision of a customized method and process for component-oriented and model-based software construction;
- Provision of automatic code generators for deriving functional code plus corresponding test code;
- Verification of the process, the concepts and the generation within a mobile computing scenario.

The MDTS scenario comprises a technical maintenance personnel who is assisted by experts at central facilities supported through a mobile communication and information infrastructure. This is a typical distributed communication system with interactions taking place between different platforms, at varying resources and bandwidth.

Frame 4.1: MDTS objectives and application scenario.

Chapter 5: Application Systems – Design Implications

In this chapter, inherent characteristics and fundamental elements of co-operative work are used to expose the difficulties of employing established technology to mediate a social process, which by its very nature is so susceptible to inconstancies, differences, and fortuitousness, and is permeated with subtle occurrences of profound meaning that are difficult to reproduce in the digital world. Amidst the fertile arena of research possibilities, such as underlying technologies, system architecture, virtual simulations, and social issues, the author has focused the investigation on the features of a system to support a distributed co-operative work, in which strong asymmetries exist between the relevant components of the mediated process. This is a novel situation promoted by the myriad of technologies for mobile computing and the extension of information services to support other types of users in field practices.

To be resilient in the presence of such asymmetries, the system has to adapt functionality according to the diverse circumstances and constraints related to the usage model, and as defined by the resources, human agents, and application context. The proposed development approach considers these entities as a functional unit and focuses concerns primarily on the human agents and their goal to co-operate with each other.

5.1 Computer-Supported Co-operative Work

The reason for people to pursue co-operation can be for purely emotionally rewarding purposes or for specific task-related goals, and by doing so, the effect is increased satisfaction or higher productivity. From other points of view, co-operation can be sought individually or be imposed managerially, and the relationships can be one-time encounters or enduring. The most natural form of encounter is a face-to-face meeting in a single physical environment. However, progressively, technological advances in the areas of telecommunication and digital information have contributed to enabling this kind of social process among people based far apart at different locations, allowing new co-operation practices.

A situation, where multiple human agents congregate to discuss, design, or perform different types of collaboration supported by a computer apparatus, has been established as Computer-Supported Cooperative Work. Thus, CSCW can be said to be a combination of two components: a technical system and a social process, and these require certain competencies from the tools and media to handle knowledge exchange, and from the social agents, especially to cooperate[9]. In terms of further terminology associated with this subject, researchers, system developers, and marketers gravitated towards "Groupware" as a term to denote the team-oriented product that supports cooperative work, as presented by Shneiderman in [Shneiderman98]. Much earlier, Greenberg [Greenberg91] already used an additional attribute: "software that supports and augments group work". If a position should be required, the author would adopt this definition by Greenberg, because the technical system may modify ("augment" or even constrain) the social process. Actually, since the term was coined, which is usually credited to Johnson-Lenz (first used in print in [Johnson-Lenz82]), this definition has been the subject of great controversy, one calling it a constrained view, another, too broad. Hence, there has never been a consensus on what system could be considered "groupware".

[9] When the goal of the joint-work is for purposes of training or professional updating, sometimes the term Computer-Supported Cooperative Learning (CSCL) is used instead. In this context, Pfister mentions a third component to CSCW–"a pedagogical didactic method"–, and adds–"competence to learn"–as a new requirement [Pfister00].

Regarding the research efforts, the focus has been, therefore, devoted to the design and evaluation of new technologies to effectively support the social process of work, typically among distant partners. Yet, any research endeavour in this field has an interdisciplinary basis involving–in addition to computer sciences–organisational and social psychology (sometimes called sociometry[10]).

5.1.1 Collaborative environments and technology characteristics

As mentioned in the previous section, a face-to-face meeting is the most natural form of human encounter for collaboration. In addition, it has long been accepted as being the most productive form, because the availability of all possible communication channels among the participants promotes consistent interactions and a collective understanding. Properties of the physical world contributing to this phenomenon, as Watsen et al. cited in [Watsen97], include the full-sensory experience, the full-body gesture information (even the act of tugging at others' clothes to get attention), no latency overhead, and the common experiences shared by the partners.

With technological support, the collaboration can also be realised among distant partners. However, despite prophecies and beliefs, a drawback for achieving similar productivity is the fact that a pre-programmed digital entity is responsible for handling the shared information space, and for co-ordinating, merging, and moulding human interactions. Furthermore, this mediation generally introduces functional and cognitive seams (discontinuities, as named by Billinghurst et al. in [Billinghurst97]) into a collaborative workspace, which, among other things, constrains or forces shifts in the way people interact and work.

Lastly, in the course of a social process, we are immersed in a sea of social information, grounded by a familiar set of cultural norms and mores, to which we have evolved an exquisite sensitivity and are most attuned, and which enable us to draw on our experience and expertise to adjust interaction. With a digital mediation, we can be almost socially blind; subtle cues may go unnoticed, activities and constraints from others may be not visible, and the human-computer interaction demands persist as a cognitive overhead to the primary human-human interaction.

Recent technological contributions seek to provide remote partners (i.e., networked users of a groupware system) with experiences similar to those of an 'in-person' interaction (as the users would be at the same location) by bringing them together artificially to a common interactive 3-Dimensional (3D) Virtual Environment. However, the simulated interactions in this environment are mostly restricted to communications by object manipulation, audio, and gestures from avatars (anthropomorphic graphics). From the early pioneer projects, such as "DIVE" (see [Hagsand96] or [Carlsson93]), with their body-icons, until more recent ones, such as "The Virtual Showcase"(see [Bimber01]), much progress has been achieved, both with more realistic simulations (e.g., spatial Audio, 3D scenarios) and with the underlying technology, such as agents and high-bandwidth networks. The available communication channels do improve the collaboration process; but, in these virtual environments, the partners still have little chance to deal with any relevant artefacts of their real world and to have parallel interactions.

Diverging from the idea of fully synthetic worlds, other technological contributions seek to combine the properties of being "in-person" with the sharing of the digital contents for an interactive collaboration. Some techniques include using large projection screen panels or

[10] Sociometry is appointed as the study of relationships within a group of people. Sociology would concern the human society, its development, structure and functioning.

projecting a virtual image into a common ‘space’, as with CAVE (see [Cruz-Neira93]) and Responsive Workbench (see [Krüger95]). Unfortunately, most of these techniques require cumbersome and expensive hardware and optics, are location-dependent (unpractical for most office conditions), and there are still problems in offering the involved users a uniform view of the shared virtual objects and intuitive and natural interactions.

More recently, a very promising approach for supporting co-located partners emerged: multi-user collaborative Augmented Reality (AR). An enabling technology is based on optical see-through displays (HMDs or hand-held panels), where the users’ natural view of the real world is optically combined with synthetic objects. Noteworthy applications can be mentioned: “Shared Space” [Billinghurst98], “Transvision” [Rekimoto96], “Studierstube” [Schmalsteig96 or Szalavari98], and “Virtual Round Table” [Broll00]. Not to diminish their well-deserved merits, it must be stated that these solutions involve computations, which are heavily dependent on rich processing resources, and for which real-time performance is still a requirement that is very hard to meet. An interesting research work calls the attention that, even if the partners are co-located in such AR space, simply the head-mounted displays have a negative impact on the human-to-human interaction, because they occlude the users’ faces and block eye contact; in this work, they come up to the curios approach of synthesising facial images in order to recover the eye-contact and gaze awareness between the partners [Takemura02].

Another enabling technology to collaborative AR uses video images of the real world and mixes them with digital images. Here, the latency requirements are less strict (unless the application domain demands it), and for distributed environments, it seems the more feasible method. The exploitation idea and the benefits of such an approach in an industrial scenario are presented by the author and colleagues in [Brunetti00].

In this thesis work, the author focuses his research on enabling remote partners to opportunely establish a common collaborative environment. Furthermore, they should not be separated from their real world and objects, whose inclusions in the conversational setting should be plain (i.e., the shared workspace should be just a subset of the interpersonal space). In addition, in the event of collaboration, there should be no difficulties in archiving and retrieving conversation records (a drawback of the solutions mentioned previously). The video techniques for collaboration have been applied within the developed prototype, to be presented in a later chapter.

5.1.2 Heterogeneous partners and worlds

Considering the participants of a co-operative work, each of them has his personal conduct towards others, might have a different role in the communication and working process, uses different knowledge and experiences to analyse the information content, has different cognitive properties to process and assimilate information, and might be interested in different aspects of the outcome of this work[11]. Furthermore, in the case of a geographical dispersion of the participants, each of them is differently influenced in many senses (such as perceptively) by the respective physical environment and operational conditions.

Further asymmetries between computer-supported collaborators emerge from possible differences in the equipment used for the message interchange and interaction. For example, these differences can result from:

[11] Some research groups would intensify their differences, saying that each of the participants might belong to a different Community of Practices; for more details on this subject, see [Preece99] and [Wenger00].

- a voluntary setting, where a person prefers to use a new model of an interaction device;
- an operational case, where a person has to use a distinct computer whose performance and interaction mechanisms might put the consistency of the distributed information content and the human interaction in jeopardy; or
- a task-oriented arrangement and personal role, where a partner is responsible for in-sourcing information from his context to the system (for further processing or as the discussion content) through extra appliances, such as a video camera, sensors for biometrics and environmental information, or location systems, and the other partner has the information processing systems and other material relevant to this context on hand.

Additionally, consideration needs to be given to the network links connecting this equipment and these people. The differences here include speed and transmission characteristics, middleware services, and topology, which prevent a consistent performance of adopted communication protocols and quality of service.

Figure 5.1 depicts a CSCW scenario where two partners experience extremely different usage patterns. The wall between them stands for all the mismatches between the two worlds and the difficulty of bringing them in contact.

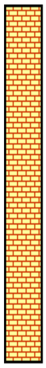


Figure 5.1a: The office partner.

Figure 5.1b: The constrained mobile partner.

Thus, it is a great challenge to bring groupware to an efficient performance level in the midst of such distinct circumstances and requirements. An adaptation of the system instantiation and user interface at each end-user's setting will result in a performance sufficient for each individual usage model. However, it is fundamental that the Shared Problem Representation (as named and similarly advocated by Karsenty in [Karsenty00]), which allows users to articulate their individual contributions, does not contain discrepancies, and thus, does not induce divergent interpretations of a problem, incompatible individual actions, and erroneous decisions.

5.1.3 Effects of a digital intermediation

Having a functional tool to support message interchanges between human beings who are not collocated constitutes the basis for a mutual collaboration process. This basis, however, includes tool features, which may extend their agencies in the sense that they also affect the process; this means, some features of this tool can considerably change the value and effect of each individual element within the collective action.

In [Kuhlen00], we can find a remarkable investigation and very illustrative results concerning 'not-designed' effects on employing a digital system for a traditional face-to-face process. For the author, Kuhlen, decisive in this investigation were the social and physiological implications of the realisation of oral academic exams via videoconferencing; some results showed that these implications could even go against examination requisites. This is worthy of elaboration in an annotated summary of the main conclusions of this investigation; these conclusions are typically expected in relation to several social processes and give rise to ideas proposed later in this chapter.

- "A system, in which a window revealing another person's face and voice is the only information source, leads to more rationality in a testing situation."
    - Test with video brings a uniform, level-down effect, because the *constrained use of senses or channels* leads to a more objective evaluation. *Only what is transferred through the direct expression of the face and spoken words will be counted*. Tactile and olfactory information also represent context factors to be taken into account, but these signals are eliminated in video. This gives rise to the supposition that the examiner can have a better appreciation of the examined person, because some (possibly) negative signals are not there.

      Similar uniformity happens in other collaboration scenarios where social mores (often hierarchical) and power relationships (e.g., ability to use gesture, voice tone, posture, etc., to help impose own view) lose their effect.
    - The examination is reduced to a rational exchange and questioning of knowledge through pre-formulated questions. With oral examinations, the verification of rhetorical capability and the ability to respond to unpredictable situations while under pressure is also in the foreground.

      In a face-to-face situation, an examiner is able to notice how the examined person is reacting and steer his questions appropriately. For such perception, nods and eye contact have a meaning, questioning and furrowed brows another, yawning and fidgeting still another. But this *perception is constrained in video due to a reduction of sensory transfers, or due to more pragmatic factors, such as the direction the video camera is pointing*.
    - If the system does not offer the possibility for ad hoc free sketches (through electronic white-boards) during explanations, *another channel is eliminated*, primarily to the disadvantage of the examined person.

      Thus, the system and its "possibilities" constitute not just the medium, but have a strong effect on the didactic aspect of the process.
- "The examined person may feel more relaxed, because the examiner is not present, but, on the other hand, irritation may appear more readily in an electronic medium due to the limited possibilities of feedback."

  This latter happens, for example, due to a low social and context awareness:
    - In the instance that one person reacts to something, whereas the remote person has no clue of its existence or occurrence, for example: someone entering the room, or sounds whose origin (e.g., from a bracelet or watch-chain) the remote partner cannot perceive.
    - Due to long inactivity of a partner, the other person cannot be sure whether his contribution is being conveyed or whether the network is simply not stable anymore.
- "The number of interruptions or overlapping is smaller in comparison to a face-to-face situation."

A dictated interaction flow may clash with an examiner's personal methods.

- "Attention must be paid, not just to the process of question and answer, but also to the technical operation of the computer, combined with the concern of whether the transmission is still stable or not."

  Cognitive overhead can bring negative consequences, especially for the examined person.

- "The presence of all the involved people cannot–at any moment–be proven or validated."

In a similar course of investigation, but extending the computer-mediated communication to larger social networks, Jones presents in [Jones00] a taxonomy of comparative factors related to on-line and face-to-face conference environments.

The presented shortcomings of the digital system that transform the social process are, however, not inherent and can have their effects lessened by special features of the system and by a better consistency of the shared workspace. Additionally, the author claims that it is still possible to preserve essential qualities of in-person collaboration if at least a shared awareness of constraints and experiences is offered to each partner, making them visible to one another. Erickson and Kellogg call systems with such visibility "Socially Translucent Systems" (translucent and not transparent due to tensions between privacy and visibility and the respective compromises to be observed) [Erickson99] and [Erickson00]. They investigate this kind of consideration in the development of a system called "Babble", aimed at providing an environment for supporting long-running and productive conversations among members of small- to medium-sized groups. They also remark that "in situations where an awareness of constraints is lacking, the interaction may break down, with people's communicative acts failing unexpectedly".

To obtain this awareness of constraints and experiences, a circumspect assessment of the resources available and usage models has to be performed. Afterwards, the respective values can be selectively distributed to the partners, and concurrently used by the system to adapt itself to the individual circumstances.

To verify these assumptions, the author resumes with the study case described in Chapter 4, where an expert in the office assists a technician during his field activity. In this 'focused partnership', there is also a closer intimacy between both partners and, hence, dedication and patience prevail. The groupware system, conceived to support this kind of work, is further detailed in the next section.

5.2 Characterizing and Classifying a CSCW case

A CSCW case can be characterized and classified according to certain criteria (a compendium of relevant references are quoted by Schlichter et. al. in [Schlichter01]) that help to explain task requirements and recognize technical requirements. This acknowledgement orients the development approaches as mentioned in section 5.1.1.

Resuming with the application case described in Chapter 4, a nomadic technician occasionally needs to summon a remote expert colleague to cooperate in the accomplishment of a field-engineering task; this task could be one of problem solving or be part of a training program. This synchronous assistance might last the entire task duration or occur intermittently.

- **Time-Room Matrix**–A two dimensional classification according to place and time of event occurrence. In the scenario, the co-operation occurs:

  - in *different places*; though, the "different places" has an attenuation, because one partner (the expert) ought to be provided with an enhanced awareness of his remote partner's work place, as he would be co-present, and with the possibility to embody interactions, or refer and point to objects (see project "GestureMan" [Heath01] for a inspiring, remote controlled laser pointer) in the remote domain.

  - at the *same time* or at *different times*. The former corresponds to the periods of synchronous interaction over the shared digital workspace; the latter, to the periods of sometime compulsory disconnected operation (to save battery charge, for example) when one partner works out the content (for example, includes annotations) while the other waits.

- "**K-Orientierung**"(C-Orientation)–Functional orientation towards **C**ommunication, **C**oordination, or **C**ooperation: The support for *cooperation* should be substantial, because the pursuance of a common goal is the primary objective, and equally, for *communication,* because the common understanding of the problem through information exchange is critical. In the two-party task, support for *coordination* is less critical in the sense of controlling actors, access, or conflicts, and more so in controlling consistency and user participation (i.e., the state of his connection).

- **Task-Oriented Functional Class**: An electronic conference system with synchronous and asynchronous interactions.

Initially, it can be presumed that a multimedia conference system would suffice for the partners to exchange knowledge and data relevant to the task. Content data to this CSCW would be in the form of electronic documents, pictures, animation sequences, or video for presenting dynamic phenomena; and the partners would use voice plus personal annotations and remote pointing to convey implicit knowledge.

With video showing each other's faces, as in traditional desktop videoconference settings, the eye contact may enhance the sense of intimacy and co-presence among the conferees. However, in this application case, the cost/benefit ratio of this feature is questionable, and further, display resolution and limited network bandwidth can reduce its efficiency. With just a video camera pointing from the side of the technician's head outward, his visual perception of the problem would be instantaneously conveyed, and, as a whole, it would also enhance his partner's awareness of other physical elements related to the actions as they occur. By mixing this discussion content with digital annotations or remote pointing, their perceptions are even augmented.

Figure 5.2 complements Figure 2.1 from Chapter 2 with illustrations of video frames, which the colleague back in the office uses to follow the procedures of the mobile technician and to give convenient instructions through annotations.

The implementation of a conferencing system for the illustrated scenario seems straightforward, but it is by no means trivial. The solution must meet stringent and distinct requirements in order to become a useful tool for the end-users. In addition to the task requirements and those of the individual users, there are different usage models and different platform arrangements to be supported. As previously advocated, an important feature for a system subjected to such asymmetries is the ability to seamlessly adapt functionality, interfaces, and contents to the fluctuating requirements. To reiterate, this was selected as the focus of this research work.

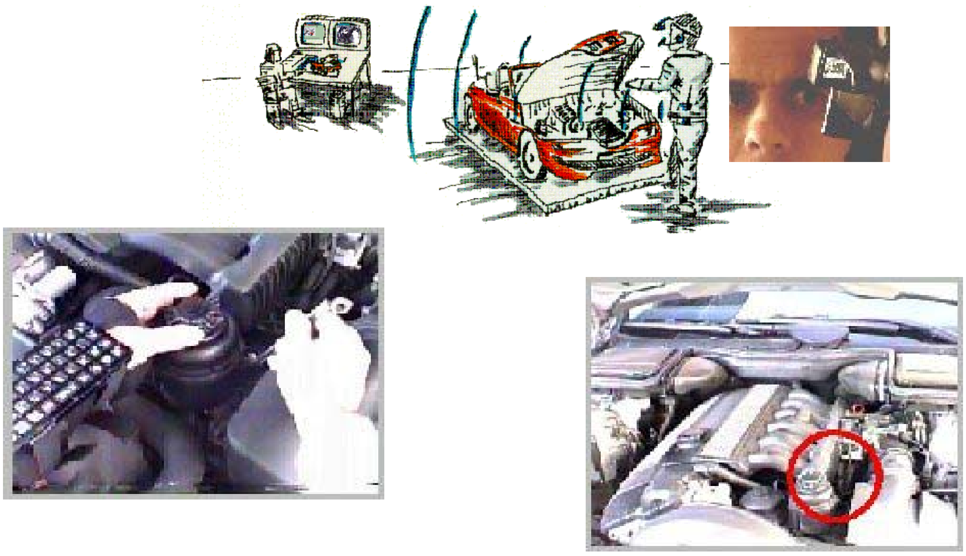


Figure 5.2: Remote assistance through a conference system including video.

In the next section, studies concerning system adaptation are presented, as well as design recommendations. Consequently, these are then applied in a prototype described in the next Chapter.

5.3 Application System Adaptation

In this section, the author clarifies in detail his motivation to focus his research on areas that have been very neglected up until this point, namely, asymmetry and adaptation issues amidst the components of a CSCW concept. The pursued goal is to be able to effectively support the social process, even in conditions that are atypical and unpredictable for the involved agents. In general, the concerns and efforts will gravitate towards the part that poses more obstacles and stimulus to this challenge: the mobile components.

5.3.1 Motivating facts and justifications

The technical resource cause - varying configurations and evolving technology

Progressively, distributed application systems have been developed, all the while taking for granted high-speed wired networks and plentiful processing resources in all of the client-host terminals, which are typical of an office environment. However, with the explosive availability and popularisation of new mobile devices and wireless network services, gradually services had to be scaled up to attend the huge diversity of client profiles wishing to access them. Hence, service attributes started to be judged by relatively new criteria, such as price/performance ratio, or possibility of detailed control; and, as never before, a guarantee of Quality of Service was a much praised attribute. Therefore, currently, an essential feature for any application system that might be accessed over mobile platforms is the ability to tailor its procedures according to the possible profile of hardware, interaction devices, and network connections that render different configuration and performance values to the system.

There are several approaches to 'mobile-enable' a traditional application system, which would allow it to perform more efficiently across slow wireless links and limited platforms. Hild and Robinson named such action "mobilize applications"; in [Hind97], they presented some examples, which propose anything from extensions and modifications in TCP/IP, to modified client-server architectures or transaction modes, and user interface. However, a system version that is extremely specialized to this particular wireless suite might also be restrictive at times and not favoured by users who would prefer to have a uniform application across all the platforms they use–mobile or stationary–(in this respect, recall the mobile user and the changing communication spaces illustrated in Figure 2.3).

Making special reference to the network connection handled by the author at earlier exercises with conference systems, the networking platform that was available and more suitable for mobile use was the cellular network–GSM–offering at best 9.6Kbps with Circuit Switched Data services (or narrow-band satellites, in this case just 2.5Kbps for the available miniature and portable settings). Therefore, most of the work consisted of surmounting the obstacles of wireless networking (as was the case for the prototype in project MOMENTS, as well). During the project evolution, wireless LANs at 1.6 Mbps became available, and so, many problems with remote information access and media requirements were apparently lessened (not necessarily solved), and new conferencing functionalities could be included. Successively, wireless networking continues evolving with startlingly rapid progress. To date, consumers and system designers can already count on data rates of 114Kbps with GPRS on mobile telephone networks, or 2Mbps in the near future with UMTS networks (actually, in-building-2Mbps; pedestrian-384Kbps; vehicular-144Kbps), or the current 10Mbps across Wireless LANs.

Nevertheless, beyond the (welcome) ‘changes’ in the technology, a user on the move, and, hence, his equipment and application system, can suddenly change network connection from a Wireless LAN access point directly to a docking station wired at 1.2 Terabit baud, and can suffer time-varying availability of signal or rapid drop in transmission, or can even simply choose (or have to choose) between connected and disconnected system operation to save battery life, connection costs, or to not interfere with surrounding electronics. Therefore, an application system has to be prepared to adjust its services accordingly in order to remain robust in the presence of such a varying environment.

Similar evolution and variations concern the mobile equipment and novel interaction devices, whose changes would supposedly always promote performance improvement or task specialization. However, besides their functional attributes, ‘secondary’ aspects, such as power consumption or weakness in the face of unpredictable usage conditions, may enormously affect the efficiency of the system, which sometimes has no option as to their specification. Furthermore, due to the close relation between supported task and physical context, and the goal to increase situation awareness, more and more interactions with external devices (recall: section 2.3.3) are becoming indispensable to obtaining elements of the real world.

Hence, an application system should be conceived to support achieving the purposes of a task, but if the employment of specific devices is mandatory, the system has to be flexible enough to greet innovations in devices and to be able to modify its use of resources and interaction demands according to the platform specified.

The human resource and interaction cause

A person will return to a computer for the information services it provides. If its operation and service constitutes all of the business activity during that period of time, and if the user is satisfied with what his efforts bring, fair enough. However, a computer can also be used occasionally during the user’s primary activity for ‘secondary tasks’ (e.g., for short consultations or calculations, or as an extended memory to record personal impressions). Hence, one can anticipate that the user’s expectations and attitudes towards the computer, application systems, and information content are different for each of the previous situations.

In terms of HCI, rich multimedia and interactive presentations strive to meet the ever-increasing demands of users, mainly in professional desktop usage and in leisure entertainment systems. In mobile professional activities, however, the information mostly has to just be there–as clear, as simple, and as easily retrievable as possible; this happens mainly because the focus of the user's attention would be on the surrounds and on his main activity. In [Kristoffersen99], Kristoffersen and Ljungberg, while suggesting interface paradigms for "handheld CSCW", formulate this latter assertion, as the HCI having to "take place" instead of "make place" in the working context. Further evocative terms and ideas advocating simplicity may be found in [Krug00], where even the book's name–"Don't Make Me Think!"–is already very suggestive of the philosophy; though not restricted to professional activities, Krug recalls that if a person is in a hurry, "looking for the bits that match the task at hand", there is tendency to "scan" the information source, looking for the words that catch the eye.

Additional human factors affecting the appropriateness of a user interface refer to feelings as they relate to preferences, sensitivity to media and stimulus in different circumstances, plus responses based on personal and cultural associations (which influences interpretations of colour, metaphors, signals, etc.), age and any possible physical impairment.

Concerning interaction mechanisms, desktop computers remain faithful to a configuration–keyboard, mouse, monitor–that, with time, has instilled certain habits, both in the users, as well as in the user interface designers (for instance, related to the dominant WIMP[12] GUI paradigm); regarding the desktop mode, this has also induced these designers to always take a full attention and direct interaction usage paradigm for granted. During mobile activities, however, these conditions are at opposing extremes, and elements from standard GUIs might be, for example, too small to be selected when in a hurry, or to permit an instant recognition of the state of the system, while the user's attention is constantly shifting between the real world and these elements[13]. In addition, as van Dam pointed out in [vanDam01], no matter how 'user-friendly' (whatever this imprecise term really means) an interface might be, it will always impose a layer of cognitive processing between a user's intentions and the computer's execution of these intentions, thus creating a consequent overload for a user engaged primarily in another task. Therefore, it is important to lessen the complexity of the interface in order to facilitate and minimize manipulation.

Lastly, the functional value of any interaction medium or the efficiency of media becomes strongly dependent on the occasion, physical environment, and task procedures. Due to the nature of the application, new types, or a combination of interaction events, occurring more naturally or even without the user's direct intervention, might be needed (for example, with gestures and voice, or imbuing the portable device with the capability to sense the user's location or proximity to other devices).

Hence, as emphasised in Chapter 4, the application system must also consider ergonomics and offer a user-interface, adaptable to the availability of the devices and their functional

[12] WIMP – Windows, Icons, Menus, and Pointers

[13] For the design of an ergonomic user interface, there are numerous studies and proposals available that one could employ. See [Isys00] for an irreverent collection of commented practices "Hall of Shame" and "Hall of Fame", or [CEN98] for standardised recommendations from the European Norm ISO 9241–"Ergonomic requirements for office work with visual display terminals", especially its Part 10 for dialogue design practice and Part 12 for the presentation of information. Despite the truth and merit of these works, few allusions are made to an HCI not necessarily bound to the WIMP paradigm and to the prevalent office desktop context. See "Section 4.3-Principles to support usability" in [Dix01] for an outstanding presentation of more general principles, which can be applied to the design of an interactive system in order to promote its usability; to some extent, these were pursued in this work.

values, and whose interaction demands shall not be oblivious to the flow of the supported task and demands placed on the user in a specific context of use.

Nevertheless, no user should be compelled to accept automatic changes, according to pre-defined software strategies, without any opportunity to opt for his favourite solution in a specific situation. Moreover, according to the application case, it is possible that a 'resource-expensive' solution becomes mandatory (for instance, the distribution and presentation of high-resolution images for medical analysis), or the user would prefer to avoid using an input mode that he believes is error-prone for certain lexical context (for example, dictation of critical numbers). Thus, before any adaptation takes place, the user should be warned about the performance change, but his option, if expressed, should be respected.

The groupware aspect

In the case of a conference system, the advocated adaptations are susceptible to new and stricter considerations. This is due to the fact that each user of a system instance might have a different hardware and networking platform available. In addition, the physical environment and operation conditions might be heterogeneous, plus the fact that the role and expertise of each conferee (user) may be completely different (add to this, the familiarity with computational issues). Hence, there may be great asymmetries between each end-point of the conference application.

Therefore, the adaptation features of conference systems have additional challenging tasks:

- They have to observe and respond to individual differences in client platforms, but
- they also have to ensure that information flowing in either direction, from one partner to the other, is consistently conveyed.
- Lastly, they have to control and inform about individual constraints; for this will help to structure the interaction among the partners.

Conclusions

Of all these facts and acknowledgements, awareness as to asymmetries and adaptation issues has created the greatest concern as the investigation area to be addressed for a conference system. In summary, the target adaptation features refer to the:

- processing resources and network availability and conditions;
- computer device characteristics and ergonomics;
- interaction device availability and user preferences;
- usage situation and physical application environment; and
- computer-supported task.

5.3.2 Adapting to the technical resources

Any service or application system, instead of shifting the responsibility of performance degradation to the limits of the platform afforded by the user, should observe and change its internal procedures automatically according to the resources available, with the goal to achieve the best possible performance.

Distinct approaches are envisaged to attend this adaptation functionality:

- At one extreme, an application system would be designed or reengineered to control the needed resources, and to decide how best to use them in order to guarantee a certain quality level for its service.

  To assist this control, the author suggests a particular 'background service' that shall continuously monitor the resources available and selectively notify the application of their relevant status and changes through a defined interface. For example, a videoconference system, being informed of a congested network, would work around the problem by lowering the frame rate of its video signal.

- At another extreme, this background service shall work closer with the operating system, and would supervise resource allocations and/or would be responsible for adaptations at protocol level, which would occur transparent to any application. For example, a management system would intercept communication calls between two communicating applications and transparently replace their native protocol with an optimised one handled by intermediary call handlers.

In a similar vein, Noble and Satyanarayanan call these two approaches "laissez-faire adaptation" and "application-transparent adaptation", respectively [Noble99]. Relevant projects related to these approaches will be mentioned during the description of the developed prototype.

The second approach mentioned is useful for sustaining legacy systems, from which, modification or access to code is denied. However, from another point of view, it is an extreme, with limited chance of providing a particular behaviour to a certain application; the adaptations of the application systems could be inadequate or even counter-productive, and leave a user without any chance to tailor or regulate them.

A deficiency of the first approach is the inability to handle the competition for resources between concurrent applications and legacy systems. Regarding the interaction with legacy systems, if one proves that the assistance from the monitoring service does improve system performance and effectiveness, one can foresee that system developers would progressively reengineer or develop their applications sensitive to it.

The proposed 'background service' will be described in more detail in Chapter 6 together with the conceived adaptation procedures applied to a conference system. Further adaptation issues concerning technical resources are addressed in the next sections: first, with reference to interaction devices, then, to the groupware system. Not to be neglected are the procedures for preparing and processing data as presented in Chapter 3.

5.3.3 Adapting to the user and his (dis)abilities

In the previous section, it was stated that the user's expectations and attitudes towards a computer, application systems, and information contents are an individual matter. Similarly, the user's cultural background, sensitivity to media and interaction channels, learning abilities, plus operation conditions significantly influence the effectiveness of any computer support to a collaborative work and can be different for each user. Therefore, it is proposed that an application system should take into consideration adaptation procedures based on the following principles:

Information that is relevant to personal needs

Especially for the mobile user, potential sources of information should be limited as much as possible, since, as formulated by Picard in [Picard97], "information overloads result in mental fatigue and negative affective responses" and leave the user with a diffuse sense of disorientation and frustration. As previously mentioned, the real bandwidth problem is inside the user's head, and technology cannot yet increase the human brain's ability to process information.

Examples of suggested approaches are:

- some error or warning messages from the application system of either partner would be posted and presented to the desktop partner first;
- for the small display, images would be presented at a magnification level focus (or cropped around) the relevant content,
- as for the case scenario, a set of relevant pictures might fully substitute a video sequence; also, the addition of video showing each other's heads should be avoided; and
- menu options or on-line help should be context sensitive and structured in different levels, with the more detailed one presented only on specific request.

Nevertheless, this kind of information filtering should not necessarily preclude the desktop partner from viewing, for instance, the same data in a much more rich and complex form; however, this process should not produce inconsistencies for the shared workspace.

Circumspect Arousal

The effectiveness of a message is based on the perception, responsiveness, and remembrance aroused in the receiver. Therefore, a user is 'affected' by a message, and subsequently changes his attitudes, only if the information content succeeds to impress him or to capture his attention, and can be easily assimilated and recalled.

Endowing a message with such ability is very important for supporting activities in which the user's attention is divided between computer operation and the working procedures. This is especially true for the mobile worker due to the brevity of time that he can allocate to the wearable computer in the course of his working activity.

Proposals for enhanced arousal are:

- Procedures that recourse to the sensitivity of media types or salient events to trigger and direct the user's attention to a problem.

  An illustrative example is borrowed from an engineering system that verifies virtually defined paths of a milling tool; as a rule, it turns a part red to indicate a catastrophic collision. However, a trainee will learn about and take to heart his error in defining this incorrect path if the visual indication were to be accompanied by a loud sound of metal being scratched. Other suggested procedures are inspired by physiological studies, which state that by the presentation of an abrupt contrast (e.g., change of apparent brightness or colour of an object, or audio levels), the respective event is better perceived; this is valuable, for instance, to call the attention of the mobile user to the arrival of requested data or the termination of a delegated task.

Another factor for the efficiency of a message refers to any visual impairment that the human agent might have or temporally experience in the application context. Therefore,

- the application should offer alternative interfaces with judicious default settings of size and colour contrast for text characters and information symbols;
- if colour is used in the display as indicator of critical information, it should not be the only cue; additional information should be included.

Interaction - Simplicity and Balance of Stimulation Fonts

For certain application domains, such as for games, there are essential features of the system user interface purposely targeted to steer and challenge abilities, reflexes, and tenability of the users. However, complex presentations of this kind, with a great number of decisions and manipulations, cause different effects on users engaged primarily in other tasks. This is because the software operation becomes a task in and of itself and may exceed the users' abilities to interact, in addition to draining them of their cognitive resources.

Pascoe et al. support the concept that a beneficial change would not necessarily be a matter of reducing the amount of interaction demands required to conduct a system operation, but rather of transferring interaction tasks to interaction modes that consume less of the user's attention (i.e., shifting interaction to unused channels or senses and in a way that is not cognitively demanding) [Pascoe00]. Though not fully agreeing with this concept with respect to the amount of interactions, the author does agree that the choice of media and interaction mode significantly influences the level of attention required of the user. Examples were anticipated in section 3.1.1 (Choosing a Media Form), but it is worth remarking, for example, that while text information is very convenient for content access (allows for an abridged, random, or repeated overview), it requires longer and more focused eye contact. Audible cues, on the other hand, are quickly assimilated and do not overuse the eyes, but do require a great deal of the user's attention in order to get a full impression.

The currently most popular (but still imprecise) term "Multimodal Interface" helps to label a proposal that

- the information access mentioned in the previous paragraph could be offered in either media or mode, or simultaneously in a synergetic blend, depending on their respective effect on the user, and their weaknesses or strengths as they relate to operation conditions. (recall: "flexible interface" and "simultaneous, dual media interaction" in section 3.1.1, Choosing a media format).

As relayed by Oviatt and Cohen in [Oviatt00], with a multimodal interface, mobile users would be able to exercise selection and control over how they interact with the computer and to switch between modalities as needed during the continuously changing conditions of use. Adaptive weighting of the input modes during environmental change can be performed to further enhance the system's overall performance.

Turk and Robertson have coined another name–Perceptual Use Interface–for application interfaces likewise characterised by techniques that combine the understanding of human natural capabilities with cautious interaction demands plus system perception and reasoning (see [Turk00]). They further name as "Perceptive User Interface" the interface capable of making the system aware of what the user is saying or what his face, body, and hands are doing (it seems that they did not go so far as to pursue an Affective Interface, as mentioned in Section 4.5).

Specifically, the author has investigated successful projects (such as EMBASSI in [Hildebrand00]) that exploit interaction modes through pointing gestures, facial expressions, lip-reading, or eye tracking, which make the procedure more natural and less demanding for the user (rather than chasing a small graphical icon on a small display while on the move). However, whereas input to a GUI, such as object selection, is a single act and certain, machine perception requires event recognition, and thus is subject to misinterpretation and ambiguity; this may raise users' concerns as to reliability. Thus, a discrete confirmation or a dual input mode might be eventually needed.

The interaction events that require no explicit or direct user intervention (often called "passive input modes"), for example, in-sourcing from a location system, are much less obtrusive and help decrease manual and cognitive fatigue; however, they, too, may give rise to concerns of reliability.

5.3.4 Adapting to the groupware aspect

Conference systems are conceived to support the process of exchanging personal ideas, mainly between geographically distant conferees, and especially when more than one communication medium has to be exploited to convey a message. As a requirement for this exchanging of ideas, the system has to emulate and distribute, or to coordinate replicas of the discussion content and any other medium that contributes to mutual understanding. Recalling the cognitive seams mentioned before, the system will be certainly rejected if it disturbs the social process or if it gives rise to doubts as to whether the message is being accurately delivered.

Regarding the operational case, where technical asymmetries between the users' platforms exist, an intervention between the extremes is paramount. In this case, the server of the conference system has to handle a sort of repository of the profiles of the accessing system clients, and then, adapt media contents and services accordingly–but above all–steadfastedly preserving the equivalence of the shared message. Adaptation procedures shall consider and comply with the following issues:

Interface for a multi-user application

For this research, the main issue related to interface design is that users might access the conference system under distinct operating conditions, and, therefore, the system should offer interface alternatives (for each specific usage model and client profile) applying the three principles mentioned in the previous sub-section. An additional challenge is to allow individuality in each interface (i.e., adaptations for a single client), but to keep functional correspondences among them.

Content filtering

A conference system may offer several conferencing functionalities, as well as handling diverse media forms, but, if in an operational case, one conferee has to use a low-resource mobile platform, he should not be confronted with receiving a media content that is inadequate for his platform. An example would be receiving a video file when there is no tool locally installed to deal with its encoding. In such a case, each partner (and the system server) has to be informed beforehand of another's deficiency and a substitute medium might have to be employed.

Some existing information systems, especially related to Web services, already offer this kind of filtering as a way to reduce the communication costs and as service customisation.

Media "distillation"

The limitations of a 'thin' mobile terminal accessing a groupware should not necessarily imply a general decrease in the features or performance of the service. Instead, the quality of a shared media-content (and thus the resource requirements) could be carefully reduced only for this constrained terminal. This situation might occur, for example, when an imminent delivery of a huge image file or video stream is confronted with low memory availability or low bandwidth network conditions.

A proposed procedure is that, before they are sent to the mobile host, the image or video stream shall have the respective resolution and colour-depth, or frame-rate, decreased–a process called "Distillation" by Brewer et al. [Brewer98], and Fox and Brewer [Fox96]–

according to the resource conditions. For preserving a common understanding and a certain level of consistency, each conference partner ought to be informed of another's deficiency and the changes in content fidelity.

Nevertheless, for such a functionality, an adaptation strategy has to be carefully established, since media have different QoS requirements, depending on the nature of the message. For example, playback video does not have the strict timing requirement of real-time video for interactive use. Additionally, in this strategy, there are aspects related to media synchronization that have to be considered. This concern emerges, for example, when two streams are supposed to be synchronized, such as voice and motion of a tele-pointer, and the latter has its pacing distilled (reduced) to save bandwidth.

From the groupware user's perspective, such effort is particularly important, because certain adaptations might lead to the misinterpretation of a message and errors; further, when evidences are uncertain, fast perceptual tasks might change into exhausting cognitive tasks (e.g., mentally guessing the real state).

Above all, the constrained user should be able to interrupt this distillation in the event that accurate outcomes for the share content are paramount for the discussion and application domain, and he is willing to bare the costs of obtaining this content.

Duties allotment

Depending on the resources available in a user terminal, certain system functionality might be too demanding for its local processing engine. Therefore, being aware of the participation of this terminal in the network, a conference server could take this functionality in hand or assign it to another terminal that is able to cope with it. Nevertheless, thinning out and assuming functionality from a system client depends highly on the network availability, possible modes of work (i.e., with temporary and voluntary disconnection during particular actions) and, if employed, middleware features.

From another point of view, the system could offer the possibility that a partner could remotely undertake interactions in his partner's domain (as mentioned in section 5.2) to help alleviate operation and cognitive demands placed upon him.

5.4 Partial Conclusions

In this chapter, some relevant aspects of the technical and social components of a CSCW have been revised. Likewise, concerns have been presented in respect to the interference that the technological mediation might cause to the social process, especially when the human communication process is already in jeopardy due to social, contextual, and technological distances.

Essential features for an application system to run over different platforms, especially when a mobile one is included, have been revised and formulated. These features concern the ability to continuously observe and adapt functionalities according to the available processing and communications resources, and general conditions of usage. In the case of conference systems, the requisites are even more complex, because, besides the heterogeneous platforms, users under different conditions might be interacting with the systems and within the network of conferees. In the end, harmony in every sense has to exist.

The proposals for realisations result from the method advocated all along this research, which is, to pay meticulous attention to the user and task to be supported rather than hailing the latest cutting-edge trends in functional features and forcing their usage in applications (and later, compelling user acceptance). Taking this user-oriented focus, the author has revised and proposed ways to adapt functionality and attend to individual requirements, so that each conference partner would be able to fulfil his computer-supported duties efficiently.

Details of a prototype realisation of a conference system for remote assistance are presented in the next chapter.

Chapter 6: Concept Realisation

The present chapter describes prototype realisations embodying all the concepts and proposals that arose during this research of adaptive system tools to support co-operative work. The prototypes use the findings and experiences gained in tests with former implementations as presented in Chapter 3, and the framework defined in Chapter 4 details the usage model and requirements of a case study. The concerns, concepts, and proposals delineated in Chapter 5 further orient the feature specifications. The result is the implementation of a service tool to allowing distinct networked and task-oriented appliances to serve as a seamless platform for a groupware arrangement, thus providing means for a conferencing system to be able to adapt itself according to the contingencies of the supported task and usage model.

Each relevant feature of the prototype conference systems will be presented and commented on.

6.1 Introduction

As mentioned in previous chapters, a profuse variety of wireless communication and information processing devices pervades the life of modern urban societies eager to access electronic services anywhere at anytime. However, the commitment of such tools to support mobility and ubiquitous service access requires features and functions that challenge application systems that–until now–have been effectively assigned to desktop usage. This happens because development assumptions, such as the availability of resources and interaction mechanisms, controllable environment, and uniform usage models, are mostly denied under the new circumstances.

A striking scenario occurs when distributed systems are required to run over different configurations of networked hardware, and concurrently, to serve users with different demands and with distinct cognitive and contextual experiences.

As requirements may vary according to each situation and even change over time, especially for the mobile side, the author has stated that, in a range that still grants the promised functionality and user satisfaction, a key system feature is ‘adaptiveness’ (user-initiated or automatic system modification). Thus, an application system should be aware of and responsive to its underlying platform, should perceive temporal requirements at the functional and contextual level, and should seek adjustments for the best alternative performance. Nevertheless, as quoted by Dix et al. [Dix00], “if information is shared among remote human agents, as with a groupware system, the consistency of the conveyed replica is of the most importance”. Therefore, there may be a conflict between adaptation strategies for individual and collective purposes.

This chapter describes two prototype conferencing systems–**MASP** and **PCom**–developed with the proposed adaptive properties and following a user-centred design (i.e., with a high regard for the supported task and respective human agent, and how technology can best serve them). Afterwards, the concepts behind two service toolkits–**ProXyML** and **RIN**– for supporting the adaptive property of the conference systems, are also described together with their prototype realisations. The chapter concludes by revealing the adaptation features and the benefits derived from this approach to dealing with distributed and team-oriented services over heterogeneous networked appliances.

6.2 The Prototype Conferencing Systems – MASP and PCom

The overall idea for the application system was the provision of a supporting tool for engineering practices, where the human agent's performance and productivity is most affected by the limited possibilities of making use of digital services for remote collaboration. The envisioned solution should also prove the assertion that it is possible to attain Computer-Supported Cooperative Work procedures, even with substantial asymmetries among the cooperating end-points, and over resource-constrained processing and communication platforms. The two case studies presented in Chapter 4 have provided the service requirements and basis for the implementation decisions.

Using the framework defined in Chapter 4 to scrutinise the application scenarios, two electronic conference systems–MASP and PCom–have been developed with functions that allow partners not physically co-located to have a discussion over information contents, with the common goal of solving an unpredictable working problem. The systems are to be employed, connecting a person in a field-based activity to a person in the office offering assistance.

For the discussion and problem representation, the media forms made available for the interaction events are: raster and vector images, real-time video streams; chat (shared typed messages), synchronous pointing mechanisms; and personal annotations in the form of text, voice-synthesised text reading; geometric primitive, and link to an audio file.

If required by, or for improving the conferencing service, the systems may interact with some external applications. For instance, these are: (i) a speech recognition commercial system (ViaVoice[14]) for voice-controlled operation or when personal annotations are to be dictated; (ii) a self-developed IP Telephony system for enabling voice collaboration between the conferees; and (iii) two self-developed monitoring tools–ProXyML and RIN–described in the next section.

MASP was the first system to be implemented based on a distributed graphical editor system for UNIX[15] Operating System called Sketchpad [Schiffner96]. MASP is written in C++ programming language and is implemented for Windows 95, Windows 98, and Windows NT Operating System; it is built in a client-server architecture, allowing up to ten conferees to participate in the conference.

PCom, though having client and server instances, has the nature of a peer-to-peer system, because it is primarily dedicated to support a dual discussion only, and one involving real-time video contents in particular. Concerning the operating system, PCom is written using the C++ library Microsoft Foundation Class (MFC) and is implemented for Windows 98 and Windows 2000. For the video streaming, it uses compression codecs commonly available in the Windows platform. Other distinctive attributes of both systems (and, which make them unique) are presented later in conjunction with the ProXyML and RIN system.

The IP Telephony[16] system for voice collaboration is implemented using Microsoft Windows Telephony Application Programming Interface (TAPI[17]) version 3.0. It enables a fine quality

[14] ViaVoice is a registered trademark of IBM Corporation.

[15] UNIX is a registered trademark of the Open Group.

[16] IP Telephony is a set of technologies that enables voice, data, and video collaboration over existing IP-base LANs, WANs, and the Internet.

setting of the audio signal and offers a good performance even under unreliable networking conditions.

Further developments, contemporaneous to the writing of this document, comprise a new implementation of PCom using TAPI functionality for both audio and video streaming. Due to the fact that TAPI includes support for the H.323 audio and video conferencing standard, PCom can be used to place calls to and receive calls from products that are H.323 compatible, such as the widespread Microsoft Windows NetMeeting. This feature is conceived to attend situations in the application scenarios, when, due to an unforeseen occurrence, the person needed to provide assistance has to be urgently sought in other places (e.g. supplier), and this place or person does not have a PCom system.

The adoption of the Microsoft Windows environment is due to the almost complete predominance of this operating system over the devices that are more suitable for the application context, and its being most frequently found among the target users. Nonetheless, the ideas, as well as most of the implemented features, are portable to other operating systems.

6.2.1 The "Thin" and the "Thick" components of the service

Using once more the framework defined in Chapter 4 for both case studies, the wireless and portable platform (hereafter referred to as the **mobile platform**) for the field worker has been specified, and similarly, for the office workers (hereafter called the **office platform**).

An optimal mobile platform comprises: a wearable–worn in a belt or vest–and battery-powered Personal Computer (MA IV TC[18]), featured with two alternatives of VGA colour display devices (XyberView HMD or CO-3 from MicroOptical Corp.), a cable mouse, a wrist-worn mini keyboard, a micro-phone and ear-pieces. Additionally, a cigar-type mini CCD colour video camera (XC-999P from Sony Electronic Inc.) and a video frame-grabber CardBus (FG-33 from HaSoTec GmbH) were also included in the platform. The speech recognition system ViaVoice is installed in the computer in case one favours voice input command instead of input per mouse or keyboard.

It is important to remark that the selection of all device models has observed specification parameters resulting from the analysis phase and subsequent requirements from the application system design; only in a few cases has the deficiency of qualitative alternatives compelled the choice. In the end, the device setting is just a proposition, to which the end-users should present suggestions and criticisms based on their individual and practical judgment, their previous familiarity with a model, and its affordability.

The author wishes to thank the project sponsors for the opportunity to acquire this selected platform. Having it was an important factor during pre-validation tests of the application system with the prospective users. With an improper hardware, though raising an opportunity for rich constructive feedback, it was difficult for all the users to avoid a premature judgement of the information service without connecting it to their impulsive distrust of the

[17] TAPI is a collection of DLLs and a programming interface for centralising and controlling telephony communications services; it supports convergence of both traditional PSTN telephony and telephony over IP. "TAPI 3.0 enables IP Telephony on the Microsoft Windows operating system by providing methods for making connections between two or more computers and accessing any media streams involved in the connection It includes QoS support to improve conference quality and networl manageability" [MSCorp99].

[18] Mobile Assistant, MA® IV TC and XyberView are trademarks of Xybernaut Corporation; RangeLAN2 is a registered trademark of Proxim, Inc.

hardware (especially with regards to potential, motion-related disabilities or safety concerns)–an additional symptom of how the *modus operandi* and the human factor in field practices are crucial.

The case study concerning aircraft maintenance also required that a mini electrical torch be attached to the video camera as a source of illumination. In addition, for this application, a novel interaction device has been designed and ordered according to suggestions made by the interviewed workers. This device is a mini board with three programmable shortcut-keys and is connected to an active keyboard splitter (Y-mouse PS/2 Board, from P. I. Engineering, Inc.) that permits the simultaneous connection of both the constructed keyboard and the regular keyboard, to the computer. The specialised keyboard can be attached to the top of the video camera, providing a convenient one-handed system operation and a simple access to complex or repetitive key sequences. See Figure 6.1 for an illustration of the hardware.

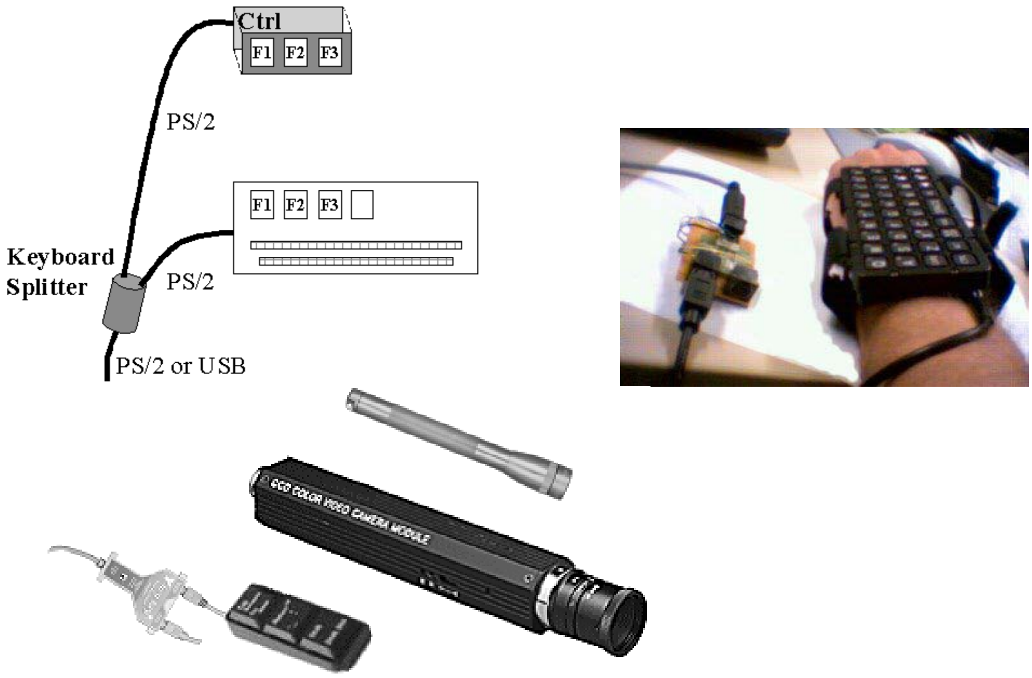


Figure 6.1: Building of device and set-up to support application requirements.

Within the mobile platform, the wireless connection to the wired network is enabled via a radio frequency Wireless LAN package (an Access Point plus a PC Card Client Adapter[19]) operating at the 'theoretical'[20] data rates of up to 1.6 Mbps (with RangeLAN2) or up to 11 Mbps (with Cisco Aironet[21] 340 Series). See Figure 6.2 for this networking structure. Despite the sufficiency provided by these values, robustness and service issues still yield to a communication network qualitatively lower than the wired counterpart; in addition, filters had to be tested and activated in the access points to achieve at least half of these promised data rates.

[19] A Wireless LAN data transceiver that acts as a centre point and bridge between the wired network and the wireless client stations, plus a network interface card radio module that is inserted into the wireless device in its external Type II or Type II PC card slot.

[20] User throughput efficiency of wireless systems is approximately 50% of the radio-signalling rate; see footnote '4'.

[21] Cisco and Aironet are registered trademarks of Cisco Systems, Inc.

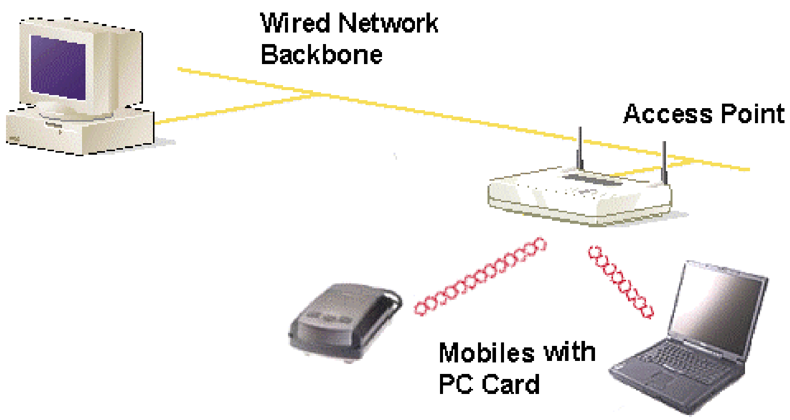


Figure 6.2: The network arrangement for the distributed service with wireless components.

The office platform in the conference service comprises: a desktop PC, fully featured with the current standards in input-output devices and corresponding performance values, and wired to the corporate Ethernet communication network.

These two operational extremes have being classified respectively as the “**thin”** and “**thick” components** of the service, whose limitations and performances influence the behaviour of the service. The human agents, who equally diverge in terms of operational abilities during service session, are also added o the definition of these extremes.

6.2.2 The Support for adaptation

Cognizant of the general characteristics of standard processing and network platforms, it is relatively easy for a system designer to abstract resources that he can take for granted (in general, the highest available) during the functional design of an application system. However, as remarked in Section 5.3.1, in the ‘mobile domain’, there is a profusion of possible platform profiles, exacerbated constraints, plus inconstancies to be considered. For a conference system over both platforms–if one does not want the thin component (or any hardware) prescribing service features and quality–the system has to provide a flexible, functional adaptation to the available resources and usage models.

Furthermore, conference systems are conceived to support the process of exchanging information and personal ideas. As a main requirement for this exchange, the system has to distribute or to coordinate the discussion content and any other medium that contribute to a mutual understanding. The system will certainly be rejected if it disturbs the social process or if it gives rise to doubts as to whether the message is being accurately delivered. Regarding the operational case, where technical asymmetries between the conferees’ platforms exist, an intervention between the extremes is paramount to avoid reaching Quality-of-Service thresholds. In this case, the server of the conference system has to be aware of the profiles of the accessing system clients, and then, adapt media contents and processes; but above all, it has to preserve message equivalence.

The strategy to support adaptation has been conceived and realized with a resource-monitoring tool. Such a tool is intended to act ‘in the background’, and conveniently and selectively report relevant context settings and resources values to the application system ‘subscribed’ to the monitoring service. With this information, the application is able to optimise and reorganise its service accordingly to the diverse contingencies. MASP was already built with a resource awareness mechanism; but now, its adaptive procedures are also able to rely on dynamic input from this external supporting process.

Figure 6.3 repeats the CSCW situation from Figure 5.1, where significant asymmetries exist among the underlying end platforms and usage models implemented by each of the working partners. It illustrates, as well, that in order to provide a successful deployment, the system server has to be aware of and respond to the underlying profiles found at each of its individual client processes.

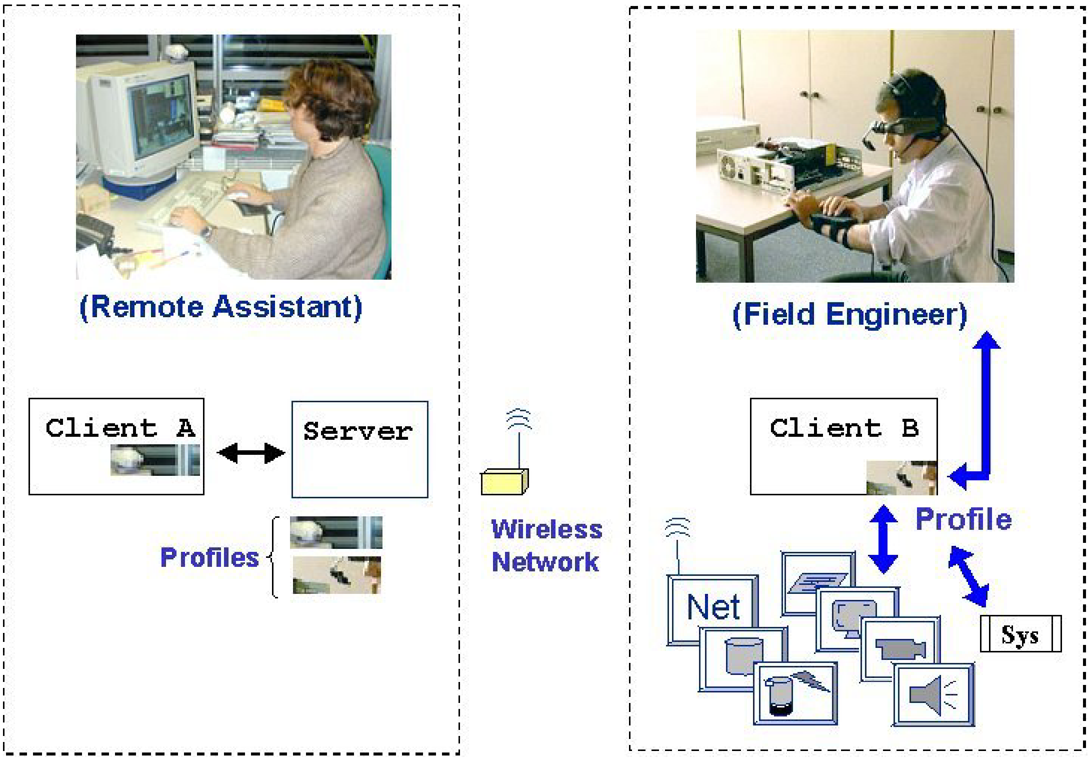


Figure 6.3: Acknowledging and responding to differences in a conference system.

6.3 Overview of the Monitoring Concept and Realisations

The conceptual idea of a monitoring tool was to develop a depot and provider of a simplified and unified view of selected resources, which would be actively at the disposal of any service interested in these resource values for its own specific adaptation. The requisite 'simplified and unified' meant that it should be easy for the forthcoming client systems to access the different types of resource information in a simple and single form. In addition, there should be an interoperability of the tool for different system platforms, allowing the tool to extend its control and reach to the distributed endpoints of networked applications. Choosing XML as a common protocol language has contributed to this concept realization.

6.3.1 Development decisions and technical implications

The System Protocol

With the goal of having a protocol, both simple to change and to decipher, and one that could reach a broad spectrum of system platforms, came the decision that it should be text-based. Furthermore, with the growing availability of XML parsers and the flexibility of XML to supply customised contents, came the decision to realise it as an XML-based command language. Therefore, the communication between each individual system involved in the service takes place via XML documents.

In case of a Request for "Monitorable" Resources

In a hypothetical scenario, a client application system of the monitoring tool would approach the tool and ask for the resource values under its supervision. The tool would then reply to the request (in the form of an XML document) with a list of all the available resource States. The proposed form of reply is described below.

Each of the State registers is identified by a unique key comprised of a Name (NAME), a Class (CLASS), and a source (SOURCE)–from which the resource State is sampled (more details in a later section). Each State exhibits one or more Value (VALUE) attributes, which are individually described by a Name (NAME) and a data type (CLASS). This data type specification influences possible internal computations with the Values. Furthermore, in order to establish a discrete value space, each VALUE node specifies several options with the contents the node might assume.

Example 6.1 shows a State node of an XML document to be returned by the monitoring tool to a client application system

```
<STATES>
    <STATE
            NAME="HOSTAVAILABLE"
            CLASS="METHOD"
            DESCRIPTION="Is TCP/IP-Host available?"
            SOURCE="NETWORK"                                          >
            <PARAMETER
                    NAME="HOST"
                    CLASS="STRING"                                    />
            <VALUE
                    NAME="AVAILABLE"
                    CLASS="STRING"                                    >
                    <OPTION
                            VALUE="YES"
                            DESCRIPTION="Host is available"           />
                    <OPTION
                            VALUE="NO"
                            DESCRIPTION="Host not available"/>
            </VALUE>
            <VALUE
                    NAME="ROUNDTRIPTIME"
                    CLASS="NUMBER"                                    />
    </STATE>
</STATES>
```

Example 6.1: Result of a request for available State.

In case of a Request for the State of a Resource

After learning of the available resource States, a client application system sets the request for a specific selection of State information, either by means of a pre-defined **Client Profile** or by direct regulation on the part of the user (in this case, the user is offered a dialog interface). Furthermore, this interest in States may have two ways of being registered and fulfilled. These are:

1. by a *single temporal request* for State values (e.g. availability of an I/O device) and
2. by granting a delivery of certain State values (e.g. battery charge) at regular intervals; this request has been named *subscription*.

In both cases, a similarly structured document is sent by the client application to the monitoring system.

In the case of a *single request*, a register is included in the XML document for each State of interest. Each of these registers offers its identification key and, eventually, an initial Value for each parameter attribute. As a response to the request, the monitoring tool returns the same document updated as to the Values.

If a *subscription* is necessary, then the attribute CLASS in the identification key is assigned as METHOD, and this requires the setting of a time interval between information deliveries. In order to reduce the amount of data in transit, threshold values can also be set to allow filtering values that should (or should not) be delivered. A videoconference system, for example, might wish to be informed of changes in network bandwidth only when its value drops below a certain level. The range for critical values (MIN and MAX) is relayed by means of the attributes of each VALUE. Example 6.2 shows the structure of a subscription for a State value.

```
<STATES>
    <STATE
            NAME="HOSTAVAILABLE"
            CLASS="METHOD"
            DESCRIPTION="Is TCP/IP Host available? "
            INTERVAL="750"
            SOURCE="NETWORK"                                  >
            <PARAMETER
                    NAME="HOST"
                    CLASS="STRING"
                    VALUE="www.igd.fhg.de"                   />

            <VALUE
                    NAME="ROUNDTRIPTIME"
                    MAX="100"
                    CLASS="NUMBER"                           />
    </STATE>
</STATES>
```

Example 6.2: Structure of a subscription to obtain a resource value regularly.

It is important to note that the protocol is independent from the basic implementation, and that the semantics for request calls are not fixed at the protocol level.

Technologies and Methods

In order to support a modular structure for the system, a component technology has been used, namely Component Object Model (COM, which is part of the Windows platform), as object broker architecture. In fact, the interfaces from all developed components allow the implementation of the same system using any other component strategy, such as CORBA or Java Beans. In terms of computer language, C++ was chosen; Java would bring the benefits of its platform-independent nature, which would allow operating system independence, but Java would not provide the needed low level control; furthermore, the system should be small and use few resources itself, so a virtual machine interpreting code was not welcome.

In addition, as a specification decision, the installation procedure of the system would have to be simple, without configuration files. In accordance with this decision, the dynamic provision of State values has been conceived to occur through an extensible module system, the so-called Plug-ins. These Plug-ins register themselves at a Component-Category, from which a potential client can later obtain, in runtime, all the objects that belong to the desired component category. All the components are 'self-registrable', which means that each binary component enrols itself at the COM broker.

Modular Plug-in Architecture

The gathering of data occurs in the activated Plug-ins, which are dynamically loaded during the start of the monitoring tool's server. Each Plug-in has a specific name, which is the name assigned to the attribute SOURCE in the State values. A Plug-in communicates with this server through a defined application interface where it delivers the requested data in the appropriate form. The server then records each XML tree in a central repository, which will later provide the available States to any client application system.

Interface to client Application Systems

Within the monitoring tool, a Manager Object was designed as the interface to the customer applications. Through this interface, a client application can learn about the monitored States available, can inform itself of a specific State's value, and can register a subscription. Therefore, the Manager Object can issue events when, for example, a State value has changed, or a new value within the range of a subscription interval appears.

The Manager Object uses an ActiveX automation interface, which makes it accessible from a large number of compilers and scripting languages. Another access option is to wrap the Manager Object with a Common Gateway Interface (CGI) application and make the monitoring service accessible through any type of Web browser.

Configuration Interface

A Configuration Interface has been developed to allow applications to indicate their interest in States that can only be set by direct user mediation. The user realises this operation through an HTML (HyperText Mark-up Language)-based dialogue.

An important functionality of this interface is the possibility to establish a connection to a Web server, through which a person can monitor the resources from his partner's platform, as well as control them. The following situations illustrate the value of this function.

- The office partner is remotely assisting the field worker with the PCom system (including the video taken from the fieldworker's viewpoint). In the event of deteriorating lighting conditions or excessive glare in the field environment, the remote partner could reset the States that influence the adaptive procedure related to colour-depth and brightness in the fieldworker's system, without this constrained fieldworker having to redirect his attention to this operation. It is important to note that, with human intervention, the adaptation is graceful and may profit from the human faculty to adapt to sub-optimal situations (video image grows darker, but remains satisfactory).
- If task-specific appliances, such as an "electronic nose" with chemical sensors for measuring hazardous gases, are housed within the portable device, then the office partner is able to detect a possible disconnection of a sensor, or the scarcity of a pertinent resource (such as battery power), and quickly take countermeasures.

Figure 6.4 shows the several interfaces, partnerships, and information treated and provided by the ProXyML toolkit detailed in the next section.

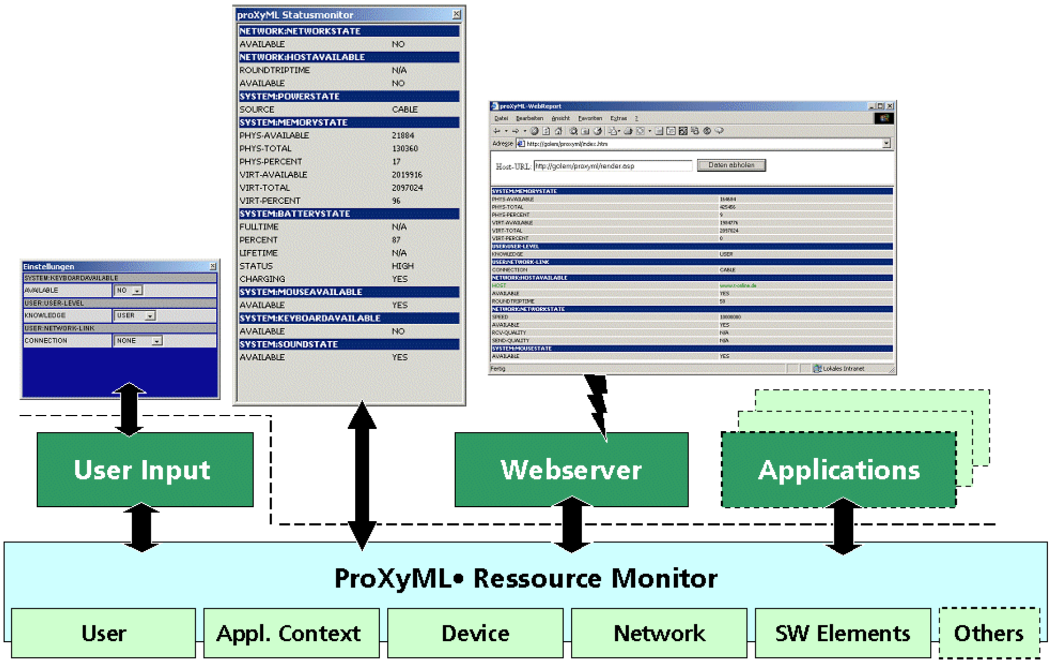


Figure: 6.4: ProXyML toolkit "business" and interfaces.

6.3.2 The Toolkit initial realisation - ProXyML

A prototype of the monitoring system has been implemented and later successfully tested in conjunction with a conference system. Internal components and other application systems relevant to the toolkit are described in the following topics.

The Central ProXyML Server

The basic system of the ProXyML Server consists of one executable module called **pxyCore**, which manages all incoming and outgoing messages. The sources of information prepared for its potential clients are encoded in the **Plug-in** modules that are bound to this server.

Internally, the server controls an XML tree, which holds the States provided by all the loaded Plug-in Dlls, and a second tree, which holds the data from each active subscription. Through this second tree, the server administrates the requests to the Plug-ins, the indicated updating intervals of State values, and the respective client applications being served. Figure 6.5 illustrates the system structure.

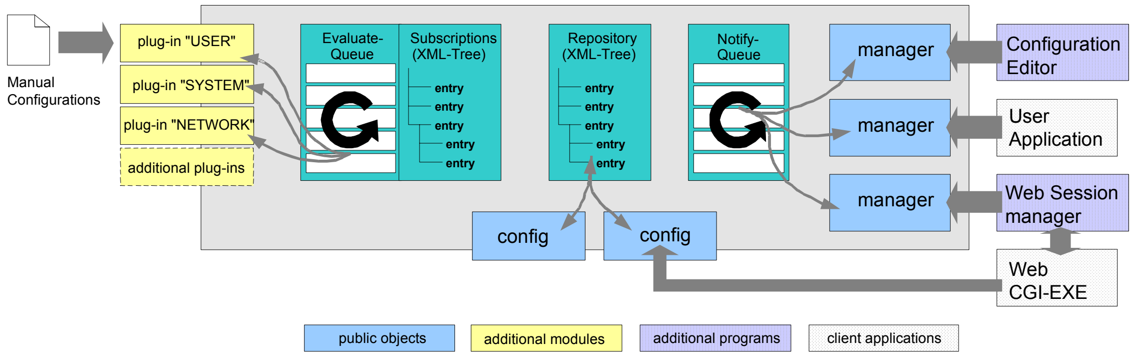


Figure 6.5: Structure of the ProXyML System.

The Plug-in Dlls

For the exploration of the proposals, three Plug-in Dlls have been implemented. The difference between them concerns their specialisation in terms of the resource state to be monitored. This purposeful separation supports the modular and scalable characteristics of the system. The Plug-in Dlls are:

- ***pxyNetwork***: This Plug-in deals with information related to the quality of the communication link. In this respect, the system orients itself to the fastest network interface available;
- ***pxySystem***: This module deals with general information related to the computer platform (e.g. availability and performance of devices, processing resources, and software) and the operating system; and
- ***pxyUser***: This module deals with manual configurable States, such as user's familiarity with computer or user's preferences, type of activity, specific quality of service required, and the presence in the environment of any active information appliances worth interacting with.

The ProXyML Session Manager

As the COM manages object lifetime through reference counting, this concept interferes with the stateless concept of Web applications. In order to keep the stateless connection with a Web client alive, a session manager is utilised; it works as a background daemon[22], keeping the connection to the Manager Object alive. Each connection is identified by a unique identifier and can be accessed, as long as it is not timed out.

The session manager supports access to all three basic objects: **Manager**, **Subscription,** and **Configuration**. This concept enables the remote-access to all features of the ProXyML system.

Toolkit Applications

Implementations of the system features were realised with the following applications:

[22] daemon: acronym for "disk and execution monitor"; a program that is not invoked explicitly, but lies dormant waiting for some condition(s) to occur.

- **sampleControl**: This application is a dialogue-based resource monitor for pre-defined usage profiles. The States of interest are specified in these profiles, which the application uses to request the relevant data from the ProXyML Toolkit. The states' values are received as an XML Document whose content is then shown to the developer or user.

  This application allows a user to accompany (in a graphical interface) the resource availability and respective temporal changes, plus the hardware reconfiguration (in the future, more prone to happen with facilities to connect devices via wireless inter-device protocols, such as Bluetooth). It is also a sort of feedback for the affected user, explaining the cause of service changes.

- **profileEditor**: With this program, a user can interactively build a new profile based on the 'monitorable' resources or can change existing profiles (see Figure 6.6, which illustrates the editing process with the respective GUIs). After recording the profile, the corresponding file can be used by the sampleControl application.

  This functionality helps users to prepare a usage profile in advance, which includes their preferences and application requirements, such as application domain, conditions of usage, physical context, object devices, platform in use, etc. This anticipatory action establishes how the system should 'behave' (i.e., what to monitor, when and why to provide notification of certain events, priorities, tolerances, etc.) before a mobile user goes into the field to execute his main task.

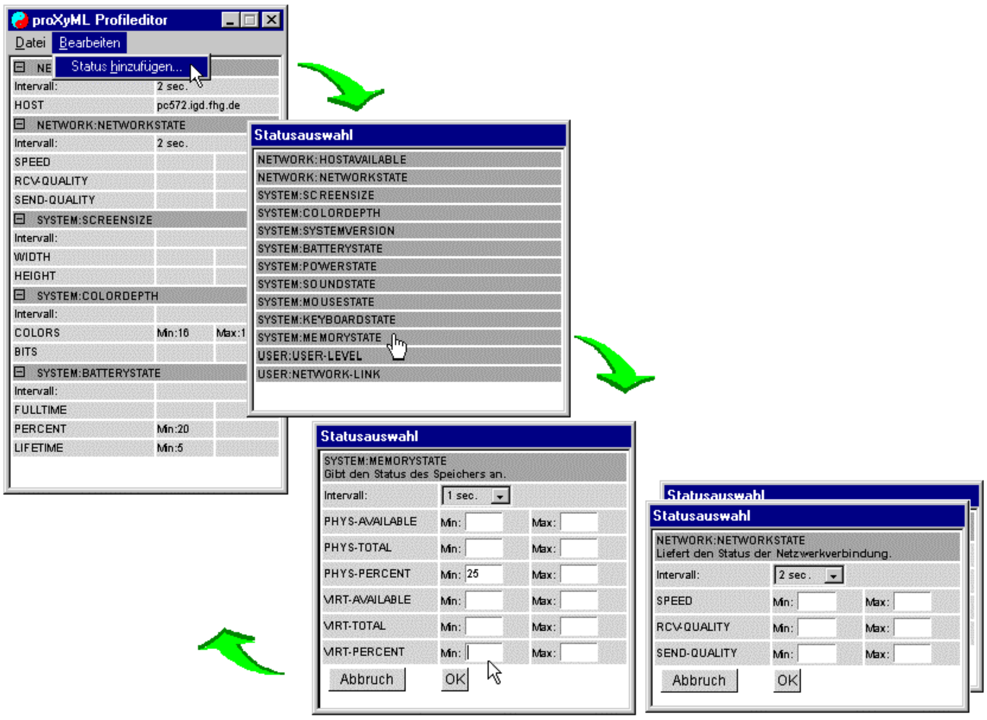


Figure 6.6: Editing a usage profile with the profileEditor.

- **pxyConfig**: With this application, the user can perform the manual setting of States through a dialogue box. Basically, these States are either from resources whose API does not allow control, or are related to cognitive issues or social parameters of relevance to certain application domains (as mentioned in the description of the pxyUser Dll).

Complementary module

For the visual presentation of XML contents, an ActiveX control element has been developed. This element is able to create an HTML file, and with the help of an XSL style-sheet, to insert the XML data coming from the container application. Hence, it is possible to generate complex dialogues with dynamic HMTL

System Requisites

The ProXyML system runs over Windows (versions: 98, NT 4.0, and 2000). The installation of Internet Explorer (Version 5.0 or later) and also the XML parser from Microsoft (version 2.5 or later) is necessary for the dialogue box. The three applications previously mentioned use the C++ library Microsoft Foundation Class (MFC).

6.3.3 The extended toolkit realisation – RIN

A further prototype of the monitoring system has been implemented, evolving from the idea to provide a distributed system (and partners) with dynamic and selective information about the local resources and resources from a remote terminal. This kind of support would enable a resource-aware system to adapt service according to the resources and performance of the underlying platform at any of the system instances. For the user, any constraint, either his own or from a remote partner, could be acknowledged, and, therefore, a remote awareness would exist and improve mutual interaction.

This new implementation, named–Resource Information Network System (RIN)–is quite similar in its concept of specialised modules for gathering resource values and uses the same component technology (the extension DCOM[23]) as in the ProXyML. The more relevant novelty in the concept is this definitive extension to a distributed monitoring and information delivery system. Complementing the previous paragraph, this functionality takes the burden of dealing internally with the distribution of resource values off of its client distributed application, and also allows that a ‘thick’ terminal assume the (acknowledgment and adaptation) process in order to alleviate its thin partner terminal.

In terms of system architecture, a kind of conceptual split between communication and monitoring functionality has taken place in the ProXyML server; much of its ‘intelligence’ (for example, the subscription control, scheduling, etc.) has been transferred to the plug-ins, which can then be better customised in their own services.

A maintained decision was to encode all RIN data using XML. At RIN, these data are essentially requests for resource monitoring and respective replies. For comparison with the subscription presented in Example 6.2, a RIN Procedure Call is presented in Example 6.3:

```
<RINPC username=““ appname=““ hostname=““>
        <PLUGIN pluginname=““>
                …                              defined according to the relevant RIN Plug-in

        </PLUGIN>

        <DESTINATION>
                <IPADR hostname=““>
                        <APP appname=““>
                                <USER username=““>
                                </USER>
```

[23] Distributed COM (DCOM) allows the instantiation and binding of components on remote computers.

```
                    </APP>
                              <USER username="“">
                              </USER>
          </IPADR>
          <APP appname="“">
                    <USER username="“">
                    </USER>
          </APP>
                    <USER username="“">
                    </USER>
     </DESTINATION>
</RINPC>
```

Example 6.3: Structure of a Procedure Call to obtain a resource value.

Such a Procedure Call is composed of two major parts:

1. a header that specifies the request sender by the username, application system name, and machine name; and

2. a body composed of two tags:

   a. Plug-in: the Plug-in addressed (similar to the attribute SOURCE in a State value in ProXyML) plus task instructions. In the case of a subscription (i.e. request processed repeatedly according to a specified time interval), the tag would be:

   ```
   <PLUGIN pluginname="RinSystemPlugin">
          <TASK  type="repeat"          (*)other options are: “as soon as possible”,
                                        “absolute time”, “compare”)
                 resource="AvailPhys"
                 srctaskid="113"
                 day="0" hour="0" minute="0" second="30">
          </TASK>
   </PLUGIN>
   ```

   b. Destination: an optional indication of recipients, who should also receive results. This indication can be any combination of multi-user, application, and host recipients.

Figure 6.7 shows an overview of the RIN system and its functional interface to a RIN-enabled distributed application.

On the left side, a conference system instance (e.g. PCom) requests the value of a local resource state (e.g. network current bandwidth), and relays that the value to be returned should be forwarded to the other conference instance, as well. On receiving the data, both conference instances would implement their strategy to adapt the service (or, using words from section 1.4.1, implement their concept on how to map the changes in low-level resources into the user-level).

With special regards to the evaluation of the network current bandwidth, a Plug-in (similar to the ***pxyNetwork*** presented in section 6.3.2) has been developed and uses efficient procedures to determine the Bottleneck and Available bandwidth[24] on the route between the two end-terminals. These procedures take in consideration, for example, the disturbing overload of the network channel, when extra data traffic ought to be generated for the measurement, and the consequent over cost, when payment is based on the among to transmitted data. Hence, in this particular case, a passive-measurement process, which takes advantage of an already existing video data streaming, is employed.

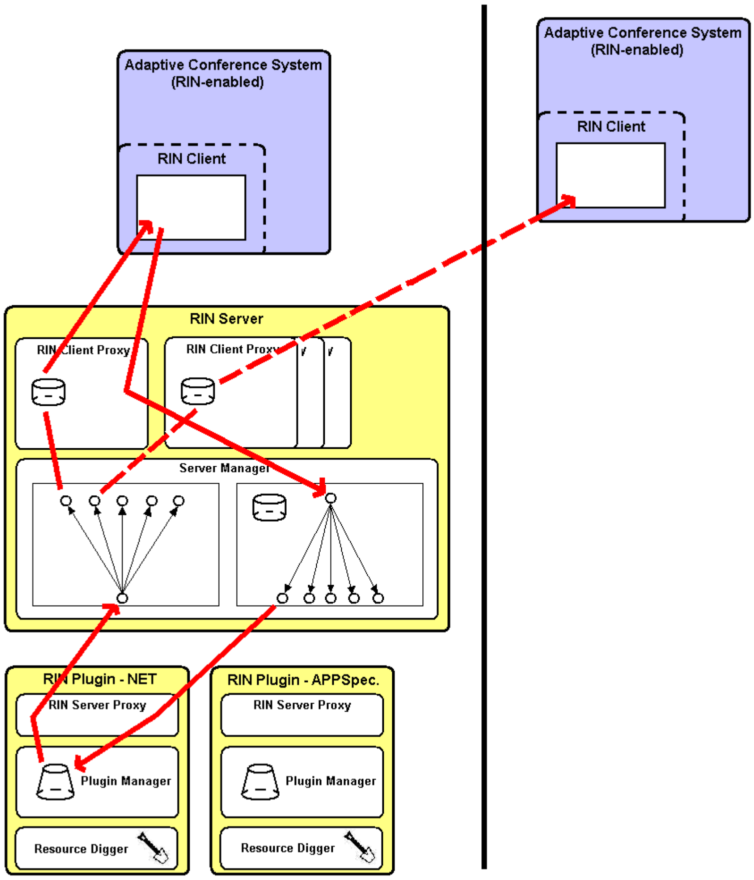


Figure 6.7: The structure of the RIN System and its monitoring services.

System Requisites

The RIN system uses the ActiveX Template Library (ATL) from Microsoft, instead of MFC, as used in ProXyML. ATL offers the possibility to develop with COM and generates very small DLLs (one includes templates instead of a whole library as with MFC). This meets the requirement of having a very compact background system.

6.4 The Adaptive Conference System Realisations

For allowing an adaptive and efficient CSCW with mobile entities, MASP and PCom profit from the support provided by monitoring tools ProXyML und RIN to dynamically adjust the information service according to task and user requirements, and available resources; and

[24] Bottleneck Bandwidth of a route is the ideal bandwidth of the lowest bandwidth link on the route between two hosts. Available Bandwidth is the maximum bandwidth at which a host can transmit at a given point in time along that route.

with both, there is a major emphasis on the most critical entities–the mobile platform and user.

The adaptation procedures implemented in MASP and PCom are presented in the next sections. They take into consideration all the experiences, methods, and recommendations presented in the previous chapters, and of no lesser importance, all the requirements and inputs obtained from the assessed application scenarios (see sections 4.7.1 and 4.7.2).

6.4.1 Adapting to the technical resources

As mentioned before, an application is informed about the existence and value of selected resources through a usage profile that is continuously updated by the monitoring tool. Subsequently, the application uses these data to adapt itself.

Two categories of profile attributes can be defined (the compounding items are indicated according to demands of the application):

1. Related to system configuration: colour-depth, display size, energy supply, network link, plus availability of sound card, keyboard, mouse, and any other device, such as video card or electronic sensors; and
2. Reporting states: system memory, battery, network link, and active applications.

Examples of implemented functionality related to the first category:

- **colour depth**:

  => Number of colours in static images or video is optimised according to terminal capability and the transmission rate of the network link. For example, if a MASP client is presented on a display monitor with 256 colours, the other client would adjust an image to this colour depth before sending it. If the network is in a critical situation, this kind of adjustment is carried out automatically (the user may interrupt this).

- **display resolution**:

  => Size and position of application window, and text font sizes are established with regard to the screen area of the display monitor.

- **availability of devices**:

  => From these data, the goal of adaptation is twofold: to overcome a missing input/output device, or, a weakness of such a device, and to balance the demands placed on the users during his mobile activity. According to the interaction device's availability and the characteristics of the application environment (which if not collected by sensors, would be relayed by the user), a different form of content presentation and interaction is offered. For example, in case a keyboard is not available, the callback action for activating a textual annotation box is automatically directed to a dialogue box for voice recording. In the next section, further adaptations to application procedures and users are presented.

The second group of attributes in the profile alerts the application when the value of a certain item has achieved a threshold limit, in which case, the application immediately activates or deactivates relevant procedures, and reports the situation to the user. Examples are:

- **battery and system memory**:

  => If the remaining battery operating time or memory availability reaches a critical state, the user is asked to save the current application content, and energy-consuming applications, such as for speech recognition or voice-controlled operation, are avoided. In addition, some internal algorithms (for example, image rendering methods) are replaced with less demanding ones.

- **communication link**:

  As mentioned in previous chapters, this is a resource value, which opens up an enormous horizon for research and possible solutions. In this prototyping realisation,

  => The observed transmission rate fosters compression procedures as presented in Chapter 2 to reduce the amount of data in transit.

  => If a poor communication link state is detected, relevant time-outs of the communication protocol for data transfer are increased, and the assignment of functionality from the client to the server application is avoided. Other relevant adaptations are described in a later section concerning adaptations to groupware aspects.

Several strategies have been empirically established to help decide how to adapt the service according to these resource values. The one presented in Figure 6.8 refers to PCom and it plays with combinations of compression rates of the video stream, and reductions of resolution and colour depth. A selection of six best strategies and subsequent adaptation steps are indicated; additionally, the graph shows the parallel gains concerning amount of data to be transmitted.

It is difficult to say that an optimal strategy would ever exist, similarly, that it would be possible to reuse it with other systems. It depends on the application domain, user preferences, the effect of reducing the fidelity of the media content, and the latency involved with the adjustment process and again, user tolerance and application demands. Fidelity of the media content is a very important factor, but quite subjective and personal; this is mentioned in a later section concerning adaptations to groupware aspects.

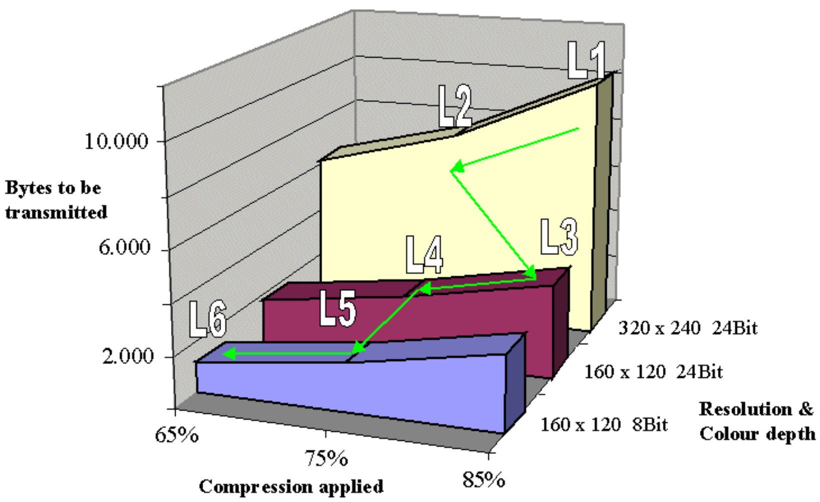


Figure 6.8: Adaptation strategy for a video content.

6.4.2 Adaptations to the user and application procedures

The goal of an adaptation of the application procedures is to make effective strides in assisting the users, without demanding any extra conscious effort beyond what they have to direct to their primary tasks.

The information on the existence and attributes of hardware devices obtained from the resource profile can be used for the adaptation of the application user interface and content presentation. Here are some of the issues and examples of adaptations:

- **information that is relevant to personal needs**:

  => The user interface, especially for the mobile user, was implemented very simply, with only the most essential output information and demands for input.

  There are two options for the graphical interface. One option is very simple with few relevant interaction channels, and the other is complete with all the necessary options and controls (e.g. for setting video format). The first option would be dedicated to the constrained worker, and the second, to the desktop partner.

  PCom also offers the possibility, while in operation mode, for a user to switch locally to a graphical interface, which shows only the shared workspace for visual contents (see Figure 6.9).

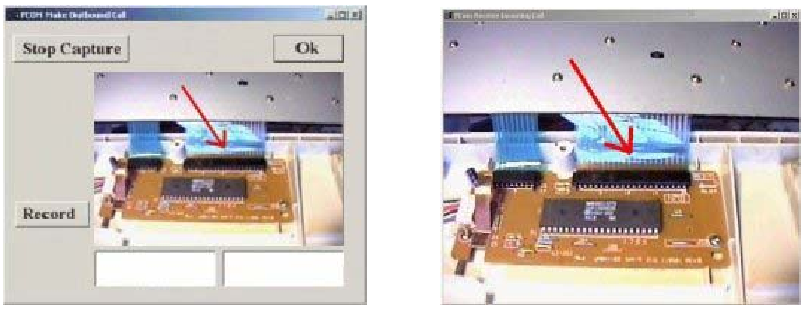


Figure 6.9: Alternation of graphical user interface.

  => Locally, the user can select the magnification level at which the distributed raster or vector graphics image is viewed: Zoom In x2, Zoom Out /2, Best Fit, Original Size, and a pre-established size in pixels.

  These enlargements or reductions are performed to satisfy the individual preferences and needs of the respective user (for example, to be able to examine small details in a diagram). This facility implies that any overlay of annotations bound to the image has to be equally adjusted. Nevertheless, individual needs might become 'less significant' in a collaborative situation and such individual resizing of the shared image might even promote inconsistency, for example, when the conferees come to different verdicts based on the absolute dimension of items quickly spotted in the shared image. Therefore, in order to guarantee equivalent visual information for the different users, the implementation of the option 'pre-established image size' became a must.

  => Conference over real-time video content, a set of relevant video frames, or over a single video frame.

Real-time video is a valuable feature and promotes a more natural interaction form, but it was reported to be superfluous most of the time and to not offer a stable subject for discussion (recall inputs from prospective users in application scenario II, section 4.7.2). Actually, video is unavoidable only when the dynamics of a task operation is the subject of the discussion. From a technological point of view, video is extremely demanding in terms of processing and communication resources (even more so, if one offers matching of whiteboard annotations with video contents), and a battery would certainly be depleted before the user predicts.

Regarding relevant video frames, when one of the conferees identifies a representative view or impression of the problem in the PCom shared workspace, he can interrupt the (freeze) the video streaming by command and the content of the present frame is then transmitted to his partner as a compressed image file. An extension of this functionality enables a group of selected frames to be stored together in the file and then transmitted. Such a selection of images is enough to give a consulted expert a good understanding of the context of a query and provides important records for a documentation of the activity.

MASP, which has not been featured to perform video streaming, implements similar functionality using a different approach. From the MASP menu, the user with the video camera elects to start a video capture, which is performed by an external program–MASP_CapVid–that shows the video capture in a new window. Upon identifying a representative view, this user selects an option to grab the image content from this window; the image data is then transmitted and displayed in the shared MAPS workspace and automatically transmitted to the other user. In comparison to PCom, one difference is that the user with the video camera is the one responsible for selecting the representative image.

An illustrative case of using this functionality with MASP is shown in Figure 6.10.

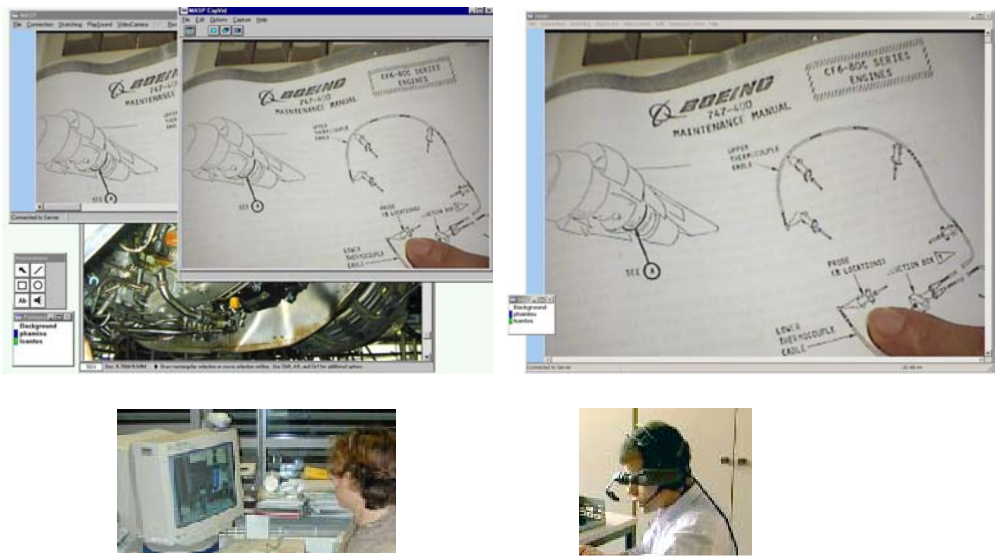


Figure 6.10: Brief alternation of arrangements and roles.

At the moment portrayed, the professional expert–the desktop user–is the partner responsible for in-sourcing the information needed to clarify the query though his own video camera (recall section 5.1.2: here, a brief alternation of arrangements and personal roles occurs). This information is in the form of a diagram found in the documentation (a maintenance manual from a Boeing 747, which the mobile user certainly would not be able to carry around with him) relevant to the presented problem at the aircraft turbine. The expert sends this diagram to the technician–the mobile user–as a picture obtained and distributed as described in the previous paragraph.

- **arousal**:

  => The visual workspace of the conference system can present the discussion content (image and overlays of personal annotation) in several degrees of magnification.

  => A tele-pointing mechanism is offered for one partner to direct another partner's attention to a specific subject or region of the visual content (video or static image) in the shared workspace. To save transmission bandwidth, the position of the tele-pointer is transmitted in a sequence of intervals (variable according to the network state).

  => A talking agent has been implemented to visually and vocally direct the user's attention to times of special (e.g. request for connection by a partner) or critical (e.g. critical resource has reached a threshold state value) events. See Figure 6.11. In the event of such critical events where the conference system is in connected mode, the warning will first go to the unconstrained partner at the desktop, who can take initial countermeasures.

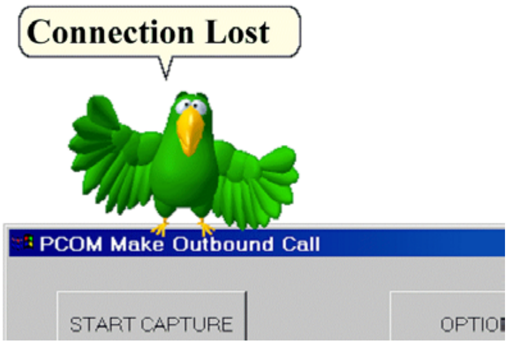


Figure 6.11: Attention trigger to reinforce the event and message.

- **balance and simplicity in the stimulation fonts**:

  For a computer-savvy user, the benefit of having a simple user interface, as presented in the first bullet, is hard to discern at first contact. Nevertheless, users participating in informal usability tests of MASP and PCom immediately confirmed the value of a minimalist interaction effort as soon as they tried to use the system in the portable equipment. This confirmation was even more pronounced when they attempted to simultaneously perform another activity.

  => On the interface for the constrained worker, several textual inputs, which were meant to increase user choices, are replaced by semantically pre-arranged selections.

  The choices (input) behind these selections are stored in textual files, which are opportunely read by the system. An example is the menu option 'Emergency', which stands for the name of a host computer and the port number for establishing a connection and the conference mode; these data can be easily modified before the worker goes to a certain environment.

=> The talking agent (presented in the previous item), if activated, can read (convert text to speech) all the incoming textual information (annotations and chat) or the constrained worker. See Figure 6.12. Using both media modes at the same time helps to compensate for the weakness of one mode in the task environment and at the miniature interaction device (, because, for example, it is difficult to distinguish the text on the monitor if glare from the sun is blinding, or since extreme effort and attention is required to read from a little monitor).

Figure 6.12: A multimodal interaction.

- **collaboration mode**:

  => The partners may choose to switch the conference to an asynchronous communication mode in order to save transmission bandwidth and communication costs. Another reason can be to avoid putting pressure on the mobile user who might need time to calculate and try the suggested action on his own. In the case of an asynchronous mode, in MASP, a discussion content (picture or video frames plus personal annotations) can be prepared or further elaborated and recorded in a session file; when the connection is resumed, this file is then distributed.

6.4.3 Adjusting to the groupware aspect

The distributed monitoring support contributes to the effectiveness of the social process. This is because a conferee is able to observe the usage profile of his partner and interact accordingly. For the system, a conference instance or server can tailor any data to be sent to the constrained client. Some of the issues and realizations of this subject are:

The visual workspace of the conference system can simultaneously present the discussion content in different degrees of magnification, with no detriment to the personal annotations overlaying it.

- **content filtering**:

  => A user is never confronted with receiving a media that is inadequate for his device, because the other conferees are informed of any deficiency. Together, they will look for an alternative discussion medium. Indirectly, this filtering helps to reduce transmission costs and battery consumption.

- **media "distillation"**:

  => The quality of shared media content is reduced according to the limitations of the client platforms, following strategies as presented in Figure 6.7. Albeit, depending on the circumstances of the application, the user can interrupt this mediation.

This procedure implies some kind of inconsistency in the shared content of a collaborative activity, but a satisfactory and best-for-everyone compromise is achieved. In addition, due to the 'focused partnership' (see section 5.1.3) that exists and is necessary in the target application scenarios, the partners will be disposed to adjust interaction to the sub-optimal conditions in order to achieve their primary goal.

- **consistency**:

  => As previously presented regarding personal needs, images and video content can be presented at different magnification levels for each partner; however, for a coherent content discussion between conference partners, the choice of a pre-established size (in pixels) for the shared image is also available (as justified in section 6.4.2, as well). In case there are overlays of annotation bound to the static image, their relative position and size are maintained.

  => In case one of the users elects to freeze the video show (as justified in section 6.4.2, as well), because, for example, he has visually spotted the problem and wants to comment on it, then a 'harmonizing' procedure takes place. This procedure ensures that the video frame, showing at the time the user elected to freeze, is saved in a separate picture file, converted to an optimal encoding format (for instance, bmp to jpeg), and distributed to the conferees. Thus, independent of the speed of the network (that means, even with a minimal difference between the frames being viewed at the different locations), this procedure guarantees that the conferees will be discussing the same information content.

- **maintaining participation**:

  => During moments of a 'standstill' in the co-operation process–and with consequently no data are being transmitted among the connected system clients–, these clients perform periodic checks of whether their connection is still active, and if not, the users are notified straight away. In most distributed systems, a server or client only realises that there is a loss of connection when they have to exchange messages. These checks are of fundamental importance, even though they consume bandwidth and might yield additional communication costs (for instance, in case billing of the network service is based on the amount of transmitted data); this is due to the fact that the wireless terminal might lose the connection just because the user goes out of range, or due to interference from the surrounding machinery.

  For the users, this information helps to solve the frustrating guesswork as to what could be delaying the feedback from a partner. In MASP, if an involuntary network disconnection occurs, a 'conference session' file (with background image plus annotations) is prepared to be used within the recovery of the conference status in the event of a reconnection. RIN is also able to provide a consistent reconnection procedure.

6.5 Partial Conclusions

In this chapter, a concept for service awareness and adaptation according to the supporting environment has been realised. It emphasises that the suitability of the complete service environment is more important than an opulent set of features for achieving an effective functioning of its components and for the benefit of the service consumers.

The conference systems MASP and PCom offer the appropriate functionality for the task and usage conditions; in addition, they exploit the constant alertness of the monitoring tools to adjust themselves opportunely, and according to the informed availability of resources, the conditions imposed by the users and the application domain, and the conferencing issues.

ProXyML and RIN were presented as enabling tools for this adaptation concept, in the sense that they are able to monitor a usage profile and selectively notify adaptive services. In addition to concerns related to technological issues, the human-centred approach helps to improve interaction and usability. Offering a remote monitoring capability, the tools also enable a remote conference partner to supervise the profile of his constrained partner, and to scrupulously trigger system adjustments aimed at enhancing the performance of the application service and conference process (adopting human reason as the ultimate authority causes the adaptation to observe social principles involved in a conference event.

In conclusion, conference systems over heterogeneous platforms have been presented as beneficiaries of the monitoring tools. However, any system or service dealing with diversity and asymmetries could similarly profit from the tools.

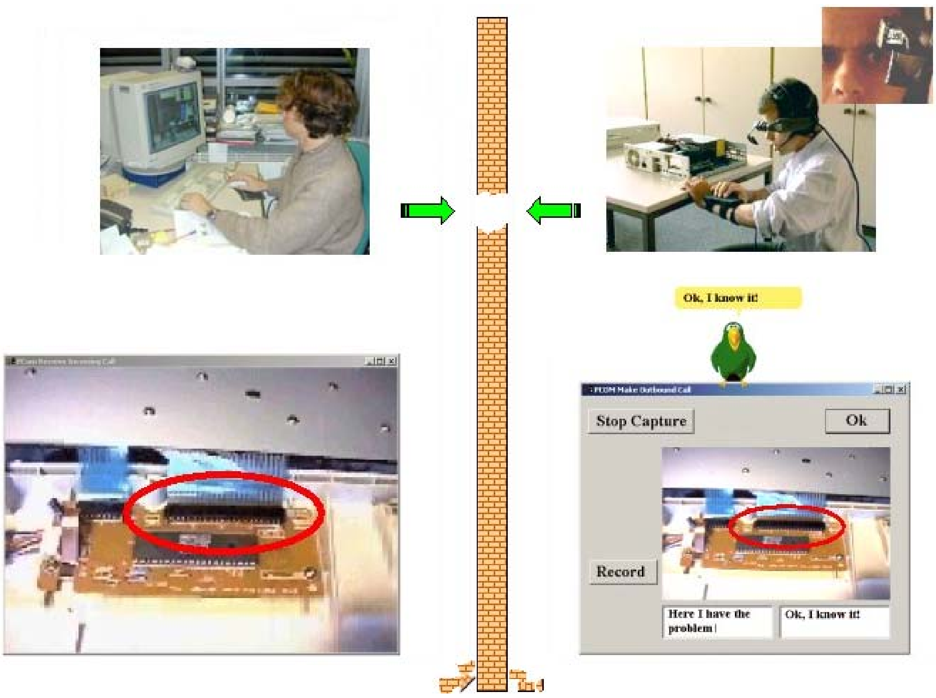


Figure 6.13: The adaptive and multimodal CSCW for asymmetric and mobile entities.

A conference system for enabling computer-supported mobile activities.

Chapter 7: Closure

7.1 Summary and General Conclusions

With this research, the author has pursued and realized the main goal of fostering the development of more effective applications for mobile applications, with the focus on satisfying the cognitive and ergonomic needs of mobile users. Therefore, all the studies and proposals were based around the concept of a human-centred approach, where technology facilitates, expands, and affects the purpose and functionality of a system, but remains a means to an end, namely to support the user in accomplishing his work.

A further challenge was to ensure that such mobile applications could also be Groupware, by which the mobile and practising engineer could get a remote support from a distant partner. In this situation, it was necessary to monitor and harmonise the differences that would exist between the mobile user and his colleague in the office. These differences are related to underlying platform and usage context.

In the introductory chapter, comments on a literature review were presented, classified by the three key themes defining this work.

The two following chapters were dedicated to appoint and describe some relevant technologies and concerns regarding data and services when dealing with mobile computing technology. The first of these chapters served to familiarise readers of this dissertation with the various technologies cited and to recall their limiting attributes in terms of contributing to a service performance comparable to that of their stationary counterparts. The second of these chapters presented important attributes of media and concepts for data and service provisioning developed within a parallel project.

In chapter 4, methods to assess user and task requirements were defined by way of a fictitious scenario. These methods were tested and revised in two real and very representative co-operative work scenarios, leading to the definition of an analysis framework. With the conceived tools, one is able to specify with more certainty, in the system pre-design phase, the necessary functionality and the technological tools to be employed.

In the subsequent chapter, relevant aspects of the technical and social components of a CSCW were presented and commented on. This followed several recommendations for system tailoring and adaptation according to individual, but also collective requirements.

Finally, the implementation of two conference systems was presented, taking into consideration all the tools and recommendations conceived and then further developed during the course of this research. These systems are able to cope successfully with heterogeneous and mobile end-platforms, and to support users with different abilities and in different conditions of usage. For each of the recommendations, the specific feature was described. Furthermore, to support this flexibility, monitoring tools were implemented, which had been developed to assist the distributed conference systems in adapting themselves according to the specified requirements. These tools were also described in some detail, along with the remark that they can be used to support any distributed system to achieve a specified quality of service.

There is a great deal of interest being shown by a manufacturing industry and by the analysed aircraft maintenance office to employ one of the conference systems in their daily business.

In addition, the monitoring tool RIN has peaked the interest of other research groups to extend its functionally to support telecommunication systems in general; in this respect, it serves as the basis for the on-going cooperative project–Model-Driven Development of Telecommunication Systems (MDTS).

7.2 Future Work

An important step for the future is to explore other technologies to enhance the contextual awareness of the conference partners. This would involve work with sensors and positioning systems and discerning how this information could be used to tailor and complement the service. Similarly, knowledge management and data mining are themes of great relevance for enabling the provision of correct and compact contextual information to the conferees. This would also contribute to saving valuable system and cognitive resources.

An important issue for further work related to RIN is data security. In the current state, RIN relies on COM/DCOM for authentications, which means that access permissions to use RIN-Servers are given in a similar way as those for access to other system resources, such as filesystem or shared printers. Certainly, when the utilization scenario extends outside corporate internal networks, RIN will face restrictions as to accessing resource values. Similar concern exists as to the misuse of persistent profile data. This persistence is useful to facilitate resuming the session after involuntary disconnections, which might occur frequently with the wireless link; however, this procedure lends itself to conflicts with privacy and security (recall the Directive 95/46/EC of the European Parliament concerning the processing of personal data and the protection of privacy in the electronic communications sector). Further research is being developed to create a kind of encryption procedure to constrain the access to the profile data.

References

[Arbanowski01] Arbanowski, S., van der Meer, S., Steglich, S., and Popescu-Zeleting, R., 2001: "I-centric Communications", In Informatik Forschung und Entwicklung, Springer-Verlag, Band 16, Heft 4.

[ASantos02] Alves dos Santos, L., 2002: "MASP-Technology for Collaboration, Support and Inclusion in Engineering Processes", In Proceedings of the International Conference CAD 2002 (Dresden, Germany).

[ASantos01] Alves dos Santos, L., 2001: "A Wearable Collaboration Solution for Industrial Environment", In Proceedings of the 2001 IEEE Third International Workshop on Networked Appliances (IWNA '01, Singapore).

[ASantos99] Alves dos Santos, L., 1999: "Wearable Computers and Augmented Reality in an Industrial Application", In Proceedings of the 19th ASME Computers and Information in Engineering Conference (DETC '99, Las Vegas, NV, USA).

[ASantos98] Alves dos Santos, L., 1998: "Multimedia Data and Tools for Web Services over Wireless Platforms," In IEEE Personal Communications Magazine, IEEE Computer Society, Vol. 5, No. 5, pp. 42-46.

[Bauer98] Bauer, M., Heiber, T., Kortuem, G., and Segall, Z., 1998: "A Collaborative Wearable System with Remote Sensing", In Proceedings of the Second International Symposium on Wearable Computers (ISWC '98, Pittsburgh, PA, USA).

[Belz97] Belz, C., Jung, H., Latva-Rasku, P., Alves dos Santos, L. and Strack, R., 1998: "Handling of Dynamic 2D/3D Graphics in Narrow-Band Mobile Services", in "Virtual Worlds on the Internet" from J. A. Vince, and R. A. Earnshaw (Eds), IEEE Computer Society Press, pp. 147-157.

[Billinghurst97] Billinghurst, M., Weghorst, S., and Furness III, T., 1997: "Wearable Computers for Three Dimensional CSCW", In Proceedings of the First International Symposium on Wearable Computers (ISCW '97, Boston, MA, USA).

[Billinghurst98] Billinghurst, M., 1998: "Shared Space: An Augmented Reality approach for Computer Supported Collaborative Work", In Journal of Virtual Reality, Vol. 3, pp. 25-36.

[Bimber01] Bimber, O., Fröhlich, B., Schmalstieg, D., and Encarnação, L. M., 2001: "The Virtual Showcase", In IEEE Computer Graphics, Vol. 21, No. 6, pp. 48-55.

[Blickmore97] Blickmore, T.W. and Schilit, B.N., 1997: "Digestor: Device-Independent Access to Word Wide Web, In Proceedings for the Sixth International World Wide Web Conference (Santa Clara, CA, USA).

[Borghoff98] Borghoff, U. M., Schlichter, J. H., 1998: "Computer-Supported Cooperative Work–Introduction to Distributed Applications", Springer-Verlag, p. 108.

[Brewer98] Brewer, E. A., Katz, R. H., Chawathe, Y., Gribble, S. D., Hodes, T., Nguyen, G., Stemm, M., Henderson, T., Amir, E., Balakrishnan, H., Fox, A., Padmanabhan, V. N., and Seshan, S., 1998: "A Network Architecture for Heterogeneous Mobile Computing", In IEEE Personal Communications Magazine, Vol. 5, No. 5, pp. 8-24.

[Broll00] Broll, W., Meier, E., and Schardt, T., 2000: "The Virtual Round Table – a Collaborative Augmented Multi-User Environment, In Proceedings of the Third International Conference on Collaborative Virtual Environments (CVE 2000, San Francisco, CA, USA), ACM Press.

[Brunetti00] Brunetti, G., Graf. H., and Alves dos Santos, L., 2000: "Virtual Reality Techniques Supporting the Product and Process Development", In Proceedings of the 5 Seminario International de Alta Tecnologia (SIAT '00, Piracicaba, Brazil).

[Butz01] Butz, A., and Krüger, A., 2001: "Orts- und richtungsabhängige Informationspräsentation auf Mobilen Geräten", In Informationstechnik und Technische Informatik Journal, Oldenbourg-Verlag, pp. 90-96.

[Carlsson93] Carlsson, C. and Hagsand, O., 1993: "DIVE--A Platform for Multi-User Virtual Environments", Computers and Graphics, Pergamon Press, Vol. 17, No. 6, pp. 663-670.

[CEN98] European Committee for Standardization, ISO 9241-12:1998.

[Chandra01] Chandra, P., Chu, Y., Fischer, A., Gao, J., Kosak, C., Eugene Ng, T. S., Steenkiste, P., Takahashi, E., and Zhang, H., 2001: "Darwin: Customizable Resource Management for Value-Added Network Services", In IEEE Network Magazine, Vol. 15, No. 1, pp. 22-35.

[Chari99] Chari, S., and Forster, K., 1999: "Wearable Computing and Augmented Reality", ", In Catalog of Princeton University Senior Theses (Thesis No. 9757), In Web URL: //www.ee.princeton.edu:80/Undergrad/seniorthesis.html, or //libnt6000.princeton.edu/theses/theses.asp.

[Cheverst98] Cheverst, K. W. J., Davies, N., and Friday, A., 1998: "Developing Interface for Collaborative Mobile Systems", In Proceedings of the First Workshop on Human-Computer Interaction with Mobile Devices (Glasgow, Scotland).

[Cruz-Neira93] Cruz-Neira, C., Sandin, D., and DeFanti, T., 1993: "Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE", In Computer Graphics (Proceedings of the SIGGRAPH '93), ACM SIGGRAPH, Vol. 27, pp. 135-142.

[Diehl94] Diehl, N. and Held, A., 1994: "Mobile Computing - Systeme, Kommunikation, Anwendungen", Thomson Publishing.

[Dix91] Dix, A. J., 1991: "Formal Methods for Interactive Systems", Academic Press, London.

[Dix00] Dix, A., Rodden, T., Davies, N., Trevor, J., Friday, A., and Palfreyman, K., 2000: "Exploiting Space and Location as a Design Framework for Interactive Mobile Systems", In ACM Transactions on Computer-Human Interaction, Vol. 7, No. 3, pp. 285-321, ACM Press New York.

[Dix01] Dix, A. J., Finlay, J. E., Abowd, G. D., Beale, R., 1998: "Human-Computer Interaction", Prentice Hall Europe (Second Ed.).

[Dyer99] Dyer, N. and Bowskill, J., 1999: "Ubiquitous Communications and Media: Steps Toward a Wearable Learning Tool", In Proceedings of the Digital Media Futures International Conference (Bradford, England).

[Erickson99] Erickson, T., Smith, D. N., Kellogg, W. A., Laff, M., Richards, J. T., and Bradner, E., 1999: "Socially Translucent Systems: Social Proxies, Persistent Conversation, and the Design of Babble", In Proceedings of the Conference on Human Factors in Computing Systems (CHI '99, Pittsburgh, PA, USA), ACM Press.

[Erickson00] Erickson, T. and Kellogg, W., 2000: "Social Translucense: An Approach to Designing Systems that Support Social Processes", In ACM Transactions on Computer-Human Interactions, Vol. 7, No. 1, pp. 59-83, ACM Press New York.

[Fox96] Fox, A. and Brewer, E. A., 1996: "Reducing WWW Latency and Bandwidth Requirements via Real-Time Distillation", In Proceedings of the Fifth International World Wide Web Conference (Paris, France).

[Fox98] Fox, A., Gribble, S. D., Chawathe, Y., and Brewer, E. A., 1998: "Adapting to Network and Client Variation Using Active Proxies: Lessons and Perspectives", In a special issue of IEEE Personal Communications Magazine.

[Friday99] Friday, A., Davies, N., Blair, G., and Cheverst, K. W. L., 1999: "Developing Adaptive Applications: The MOST Experience", In Journal of Integrated Computer-Aided Engineering, Volume 6, Number 2, IOS Press, pp. 143-158.

[Galliers99] Galliers, J., Sutcliffe, A., and Minocha, S., 1999: "An Impact Analysis Method for Safety-Critical User Interface Design", In ACM Transactions on Computer-Human Interactions, Vol. 6, No. 4, pp. 341-369, ACM Press New York.

[Gellersen02] Gellersen, H.-W., Schmidt, A., and Beigl, M., 2002: "Multi-Sensor Context-Awareness in Mobile Devices and Smart Artefacts", In Journal on Mobile Networks and Applications, Volume 7, Issue 5, pp. 341-351, Kluwer Academic Publishers.

[Gerfelder98] Gerfelder, N., Jung, H., Alves dos Santos, L. M. and Belz, C., 1998: "Challenges to deliver 2D/3D content for multimedia application in mobile environments", in ACTS Mobile Communication Summit '98 (Greece).

[Graham96] Graham, B. and Dourish, P, 1996: "Technomethodology: Paradoxes and Possibilities", In Proceedings of the Conference on Human Factors in Computing Systems (CHI '96, Canada), ACM Press.

[Greenberg91] Greenberg, S., 1991: "Computer-Supported Cooperative Work and Groupware: An Introduction to the Special Edition", In International Journal of Man-Machine Studies, Academic Press, Vol. 34, No. 2, pp. 133-141. Republished in Computer-Supported Cooperative Work and Groupware, Academic Press, London, pp. 1-10.

[Greenberg01] Greenberg, S., 2001: "Context as a Dynamic Construct", In Journal Human-Computer Interaction, Lawrence Erlbaum Associates, Inc., Vol. 16.

[Gutwin01] Gutwin, C., 2001: "The Effects of Network Delays on Group Work in Real-Time Groupware", In Proceedings of the Seventh European Conference on Computer-Supported Cooperative Work (ECSCW 2001, Bonn, Germany), Kluwer Academic Publishers.

[Hackos98] Hackos, J. T. and Redish, J, 1998: "User and Task Analysis for Interface Design", John Wiley & Sons, Inc.

[Hagsand96] Hagsand, O., 1996: "Interactive MultiUser VEs in the DIVE System", In IEEE Multimedia Magazine, Vol. 3, No. 1, pp. 30-39.

[Heath01] Heath, C., Luff, P. Kuzuoka, H., Yamazaki, K., and Oyama, S., 2001: "Creating Coherent Environments for Collaboration", In Proceedings of the 7th European Conference on Computer-Supported Cooperative Work (ECSW '01, Bonn, Germany), Kluwer Academic Publishers.

[Hild97] Hild, S., and Robinson, P., 1997: "Mobilizing Applications", In IEEE Personal Communications Magazine, Vol. 4, No. 5, pp. 26-34.

[Hildebrand00] Hildebrand, A. and Sá, V., 2000: "EMBASSI: Electronic Multimedia and Service Assistance", In Proceedings of the Intelligent Interactive Assistance & Mobile Multimedia Computing (IMC '2000, Rostock, Germany), Neuer Hochschulschriftverlag.

[Hollnagel99] Hollnagel, E., Cacciabue, P. C., 1999: "Cognition, Technology & Work: An Introduction", In Journal Cognition, Technology & Work, Springer-Verlag, Vol. 1, Issue 1, pp. 1-6.

[Isys00] Isys Information Architects, 2000: "Making Information Usable", at URL: www.iarchitect.com.

[Jamalipour01] Jamalipour, A. and Tung, T., 2001: "The Role of Satellites in Global IT: Trends and Implications", In IEEE Personal Communications, pp. 5-11.

[Johnson-Lenz82] Johnson-Lenz, P. and Johnson-Lenz, T., 1982: "Groupware: the process and impacts of design choices", In Kerr & Hiltz (Eds.), "Computer-Mediated Communication Systems", Academic Press, New York.

[Jones00] Jones, M. L. W., 2000: "Collaborative Virtual Conferences: Using Exemplars to Shape Future Research Questions", In Proceedings of the Third International Conference on Collaborative Virtual Environments (CVE 2000, San Francisco, CA, USA), ACM Press.

[Karsenty00] Karsenty, L., 2000: "Cooperative Work: The Role of Explanation in Creating a Shared Problem Representation", In journal Le travail human, Pr. Univ. de France, Vol. 63, No. 4, pp. 289-309.

[Kortuem99] Kortuem, G., Bauer, M., and Segall, Z., 1999: "NETMAN: The design of a collaborative wearable computer system", In Mobile Networks and Applications, Baltzer Science Publishers, Vol. 4, No. 1, pp. 49-58.

[Kristoffersen99] Kristoffersen, S. and Ljungber, F., 1999: "Making Place to Make IT Work: Empirical Explorations of HCI for Mobile CSCW", In Proceedings of the International Conference on Supporting Group Work (GROUP '99, Phoenix, AZ, USA), ACM Press.

[Krug00] Krug, S., 2000: "Don't Make Me Think! A Common Sense Approach to Web Usability", New Riders Publishing.

[Krüger95] Krüger, W., Bohn, C.-A., Fröhlich, B., Schüth, H., Strauß, W. and Wesche, G., "The Responsive Workbench: A Virtual Work Environment", In IEEE Computer Magazine, Vol. 28, No. 7, pp. 42-48.

[Kuhlen00] Kuhlen, R., 2000: "Der Kopf allein ist zu wenig"-Prüfungen per Videokonferenz, nfd Information-Wissenschaft und Praxis, DGI Verlag, No. 4, pp.217-222.

[Lettiere99] Lettiere, P. and Srivastava, M. B., 1999: "Advances in Wireless Terminals", In IEEE Personal Communications Magazine, Vol. 6, No. 1, pp. 6-19.

[MSCorp99] "TAPI 3.0 Connection and Media Services" and "IP Telephony with TAPI 3.0", White Papers, Microsoft Corporation, 1999, In Web URL: www.microsoft.com/windows2000/techinfo/howitworks/communications/telephony/default.asp.

[Noble97] Noble, D. B., Satyanarayanan, M., Narayanan, D., Tilton, J. E., Flinn, J., and Walker, K. R., 1997: "Agile Application-Aware Adaptations for Mobility", In Proceedings of the 16th ACM Symposium on Operating Systems Principles (Saint-Malo, France).

[Noble99] Noble, D. B. and Satyanarayanan, M., 1999: "Experience with adaptive mobile applications in Odyssey", Mobile Network Applications, Baltzer Science Publishers, Vol. 4, No. 4, pp. 245-254.

[Ockerman99] Ockerman, J. J., Najjar, L.J., and Thompson, J. C., 1999: "FAST: future technology for today's industry", In Journal Computers in Industry, ELSEVIER Science, Vol. 38, Issue 1, pp. 53-64.

[Oviatt00] Oviatt, S. and Cohen, P., 2000: "Multimodal Interfaces that Process What Comes Naturally", In Magazine Communications of the ACM, Vol. 43, No. 3, pp. 45-53, ACM Press New York.

[Pascoe00] Pascoe, J., Ryan, N., and Morse, D., 2000: "Using While Moving: HCI Issues in Fieldwork Environments", In ACM Transactions on Computer-Human Interaction, Vol. 17, No. 3, pp. 417-437, ACM Press New York.

[Picard97] Picard, R. W., 1997: "Affective Wearables", Affective Computing, MIT Press, pp. 227-246.

[Pfister00] Pfister, H.-R., 2000: "Kooperatives computerunterstütztes Lernen (CSCL)-Was ist das und wo zu nützt es?", In nfd Information-Wissenschaft und Praxis, DGI Verlag, No. 4, pp.227-231.

[Reeves96] Reeves, B. and Nass, C., 1996: "The Media Equation", In CSLI Publications and Cambridge University Press, p. 195.

[Rekimoto96] Rekimoto, J., 1996: "Transvision: A Hand-held Augmented Reality System for Collaborative Design", In Proceeding of Virtual Systems and Multimedia '96 (VSMM '96, Gifu, Japan).

[Rogers00] Rogers, Y., 2000: "Recent theoretical developments in HCI: their value for informing system design", In Web: //www.cogs.susx.ac.uk/users/yvonner.

[Shapiro94] Shapiro, D., 1994: "The Limits of Ethnography: Combining Social Sciences for CSCW", In Proceedings of the Conference on Computer-Supported Cooperative Work (CSCW '94, NC, USA), ACM Press.

[Schiffner96] Schiffner, N. and Kollmann, H., 1996: "Distributed SketchPad-Cooperative sketching system", In Proceedings of the International Workshop on CSCW in Design (Beijing, China), International Academic Publishers.

[Schlichter01] Schlichter, J., Reichwald, R., and Koch, M., 2001: “Rechnergestüzte Gruppenarbeit (CSCW)”, i-com, Oldenbourg Verlag, Heft 0-2001.

[Schilit94] Schilit, B. N., Adams, N. L. and Want, R., 1994: “Context-aware Computing Applications”, In Proceedings of the Workshop on Mobile Computing Systems and Applications (Santa Cruz, CA, USA), IEEE Computer Society.

[Schmalstieg96] Schmalstieg, D., Fuhrmann, A., Szalavari, Zs., and Gervautz, M., 1996: “Studierstube - An Environment for Collaboration in Augmented Reality”, In Proceedings of the Collaborative Virtual Environments Workshop (CVE ’96, Nottingham, England).

[Schmidt00] Schmidt, A., Gellersen, H. W., Beigl, M., and Thatet, O., 2000: “Developing User Interface for Wearable Computer-Don’t Stop to Point and Click”, In Proceedings of the Intelligent Interactive Assistance & Mobile Multimedia Computing (IMC ’2000, Rostock, Germany), Neuer Hochschulschriftverlag.

[Shneiderman98] Shneiderman, B., 1998: “Designing the User Interface: Strategies for Effective Human-Computer Interactions”, Addison-Wesley Publishing Co. (Third Ed.).

[Seshan96] Seshan, S., Balakrishnan, H., and Katz, R., 1996: “Handoffs in Cellular Wireless Networks: The Daedalus Implementation and Experience”, Kluwer International Journal on Wireless Personal Communications.

[Szalavari98] Szalavári, Zs., Schmalstieg, D., Fuhrmann, A., and Gervautz, M., 1998: “Studierstube: An Environment for Collaboration in Augmented Reality”, In Virtual Reality Journal, Springer-Verlag, No. 3, pp. 37-48.

[Takemura02] Talemura, M. and Ohta, Y, 2002: “Diminishing Head-Mounted Display for Shared Mixed Reality”, In Proceeding to the IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR 2002, Darmstdat, Germany).

[Talbert97] Talbert, N., 1997: “Toward Human-Centered Systems,” In IEEE Computer Graphics and Applications, IEEE Computer Society, Vol. 17, No. 4, pp. 21-28.

[Tsetsekas01] Tsetsekas, C., Maniatis, S., and Venieris, I. S., 2001: “Supporting QoS for Legacy Applications”, In Proceedings of the IEEE International Conference on Networking (Colmar, France).

[Turk00] Turk, M. and Robertson, G., 2000: “Perceptual User Interfaces”, In Magazine Communications of the ACM, Vol. 43, No. 3, pp. 32-34, ACM Press New York.

[vanDam01] van Dam, A., 2001: “Post-Wimp User Interfaces: the Human Connection”, In Frontiers of Human-Centred Computing, Online Communities and Virtual Environments, from Earnshaw, R., Guedj, R., van Dam, A., and Vince, J. (Eds), Springer-Verlag, pp. 163-178.

[Verso97] Lo Verso, J. R. and Mazer, M. S., 1997: “Caubweb: Detaching the Web with Tcl, In Proceedings of the Fifth Tcl/Tk Workshop (Boston, MA, USA), USENIX.

[Watsen97] Watsen, K., Darken, R., and Zyda, M., 1997: “The Shared Experience – Human Interaction Between Geographically Disparate People”, Naval Postgraduate School.

[W3C] W3C Mobile Access Interest Group and CC/PP Working Group, Reports on group activities at URL: www.w3.org.

[Widya01] Widya, I., Stap, R. E., Teunissen, L. J., and Hopman, B. F., 2001: "On the End-user QoS-Awareness of a Distributed Service Environment", In Proceedings of the Sixth International Conference on Protocols for Multimedia Systems (PROMS '01, Eschende, Netherlands).

[Ziv77] Ziv, J., Lempel, A., 1977, "A universal Algorithm for Sequential Data Compression", In IEEE Transactions on Information Theory", Vol. 23, No. 3, pp. 337-343.

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