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Human-Technology Interaction Research and Design

VTT Roadmap

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Abstract

Human-Technology Interaction is a human-centred perspective to technological innovation and development that has great relevance to the economical success of technical products and services. The aim of HTI research is to enhance the implementation of information technologies in solutions that are more functional, usable and meaningful for people. This report defines the central issues of HTI research. It provides an overview of the history of HTI research and elaborates on the different traditions within it, and the state of the art at VTT is briefly sketched.

The societal and technical drivers of HTI were surveyed to enhance understanding of the factors that effect the developments in this field. The implementation of information technologies has vastly increased the availability of information and connections in people's everyday and working activities. As a consequence, the complexity of the interactions has increased. People face difficulties with information overflow, the diversity of different devices, applications and equipment as well as with the continuous introduction of new applications and updates of existing ones. The creation of possibilities to embed technology in smart appliances and environments together with the development of multimodal interface technologies are expected to ease the use of the capacities of the information technology. However, the new ways of applying ICT have simultaneously deepened the demands on usability. Moreover, questions regarding safety and operability, security and personal privacy have gained new relevance. As consequence the implementation of technologies in use create major challenges and need for research and innovations.

Integrating the possibilities that the enabling technologies provide and the demands of the users creates a great number of research challenges. For better comprehension of the challenges we developed a systemic conception of HTI. This model makes explicit the role of enabling technologies for all three interconnected interaction aspects of HTI, "smart objects, services and environments", "usage practices", and "organisations and cultures". Another aspect of HTI is the human-centred design methodology, which needs to be further developed. All together 25 hot topics were identified as challenges for research. Their interconnections are made explicit with the help of the systemic HTI concept. In the final part of this document recommendations are made for the direction of HTI research at VTT.

Preface

VTT' s technology strategy defines focus areas of strategic research. The strategy aims at integrating long-term technology insights with the vision of the future needs of its customers. One of the aims is to combine multidisciplinary competencies to generate unique science-based innovations. Among the instruments of the technology strategy VTT has established Key Technology Actions. These are operative research actions that concretise the strategic basic research aims by establishing connections to the customers and by working on the problems, new ideas research needs that are identified in the practice. Human-Technology Interaction (HTI) is an issue that has been defined as key technology action.

In the fall of 2002 the corporate management of VTT established a small group to review the human-technology interaction issues and to form a conception of the societal and technical changes that create pressure for research and development in the HTI domain. A roadmap report was foreseen as a result of this work The group represented four research units of VTT. These units, including VTT Building and Transport, VTT Electronics, VTT Industrial Systems and VTT Information Technology, had already accomplished research regarding the HTI area. Therefore the primary focus in the work was knowledge society consumer applications, complex industrial systems, home and office environments, and transport systems.

Before receiving its mandate to produce the roadmap report the group had organised cooperation among scientists at VTT who were interested in the HTI issues and saw its relevance for the technological research within VTT. The group also cooperated with research scientists who were working on the HTI topics within the strategic technology theme on safety and operability. Scientists from the VTT Technology studies also participated in the work by providing help in the literature review. All these people formed the reference group for the HTI roadmap work. Several workshops were organised during the preparation of the present report to review and discuss the emerging conception on the human-technology interaction research, and to develop insight of the role of HTI in the VTT technology strategy.

The authors of the present report express their gratitude towards all those who benefited the work. We hope that this report aids in forming of a shared awareness of the significance of HTI issues for the future development of technology, and facilitates the practical work that needs to be done. We are convinced that knowledge of the HTI issues will attract stakeholders and industries to participate in the human-oriented technology development.

Contents

1. What is HTI and why it is an issue?

This report takes a close human-centred look at technology. The development of technology takes place in a societal setting, and is shaped by its desired functional purposes and actual processes of usage. In concert with Hancock and Chignell, we advocate the idea that human factors is not an isolated issue of design but a new perspective to technological innovation and development that also greatly affects the economical success of technical products and services (Hancock & Chignell 1995). The notion of Human-Technology Interaction was adopted to denote this broader perspective.

Within this broader approach, human-technology interaction (HTI) research focuses on ways in which technologies mediate the interaction between the human actor and his/her environment. The computerisation of tools in everyday life and work has increased the level of this mediation and, consequently, versatile new tasks and co-operative structures continue to emerge. At the same time, the tools are becoming more difficult to design for easy access and control.

HTI research is an interdisciplinary issue that focuses on the development of artefacts for human-environment interaction. This may be called the *product aspect* of HTI research. It aims at creating concepts and criteria that can be used to evaluate the appropriateness of products for use. Reaching this assumes an understanding of both human action and of the enabling technologies. HTI research also deals with the question of how to design products that are appropriate for use. This constitutes the *design aspect* of HTI research.

We define HTI as follows:

> *Human-technology interaction denotes the activity of a distributed cooperative system that the users and the technology form together with their physical and social environment.*
>
> *The product aspect of HTI deals with artefacts for human-environment interaction.*
>
> *The design aspect of HTI deals with ways of accomplishing the products.*

For this report, we opted not to resort to commonly used terms like MMI (Man Machine Interaction), HCI (Human-Computer Interaction) or even the recently used HSI (Human-System Interaction), but instead to define a new term, Human Technology

Interaction (HTI), in order to denote the changed nature of the interaction in recent years as well as the wide scope of the research involved.

We limit the application of HTI mostly to the development of information technology (IT). Like traditional tools, IT ones consist of physical hardware, but they are qualified by their software. This is a significant extension to the nature of these tools, which also creates new demands for human mastery of them. Interaction with the "virtual" or computerised world has in recent decades moved beyond the computer to involve a vast range of information and control systems and devices. Because currently available technological devices are networked, interaction is not limited to one device but involves a whole network of devices. However, the actors do not necessarily perceive their action as interaction with a "system", but rather as intentional interaction with a service provided by partially invisible technology, or with a complex and dynamic environment or processes that are made accessible via IT.

This report seeks to define the central issues of HTI research and to determine the major factors involved. It provides an overview of the history of HTI research and elaborates on the different traditions within it. The state of the art at VTT is briefly sketched, after which the societal and technical drivers of HTI are surveyed to enhance our understanding of the factors affecting the developments in this field. Next the current HTI challenges are listed, and the hottest topics for HTI research are introduced. In the final part of this document we make recommendations for the direction of HTI research at VTT.

The report begins with a rather broad scope but towards the end focuses on the topics most relevant to VTT. The units involved in the preparation of this report were VTT Building and Transport, VTT Electronics, VTT Industrial Systems and VTT Information Technology. Therefore our primary focus is on consumer applications, industrial systems, home and office environments, and transport systems.

1.1 Distinguishing different views of human-technology interaction

HTI research emerged from two lines of research. The older one originated in the engineering psychology of the 1920s, which around the time of the 1940s developed into the research domain called ergonomics. The development of industrial automation and the extensive use of IT in transport systems (especially air transport) and process industries reshaped work demands and types of workload on human operators. This created the need for understanding human cognitive processes and mental load. These issues are addressed in the field of cognitive ergonomics. This discipline aims at improving HTI in complex production or transport systems, which often have a high safety relevance.

The other line of HTI research was initiated in the late 1970s. It was labelled human-computer interaction research, because it dealt in particular with the use of computers and software systems. The characteristic context of use was the office. Notwithstanding the differences, both lines of HTI research initially focused on issues of the user interface. Today, the traditions of HTI are merging, mainly due to advances in information and communications technology (ICT). This technology provides a global infrastructure for all human activities.

HTI is understood as a multilevel phenomenon that should be studied from many different perspectives. The user *interface* level constitutes the first level of HTI. It focuses on the user's operations in making use of that part of the technology that is designed for the interaction purpose, and that part of the technology that enables this interaction. The second level of the interaction may be defined as the *task* level: the focus extends to the usage situation and the analysis focuses on the situated goals and conditions of the tasks accomplished with the technology. The third level is the *organisational or societal level* and the focus extends to wider contexts and cooperative units. In work-related applications this often includes the organisation and its information systems, trust in new technology, or the cultural prerequisites for technological change. In other applications the societal context may involve, for instance, the social situation and the cultural norms and conceptions related to the adoption of new artefacts. In transport systems this may mean management of the traffic flow or use of different transport modes.

Figure 1 illustrates the various perspectives in studying, designing and evaluating HTI.

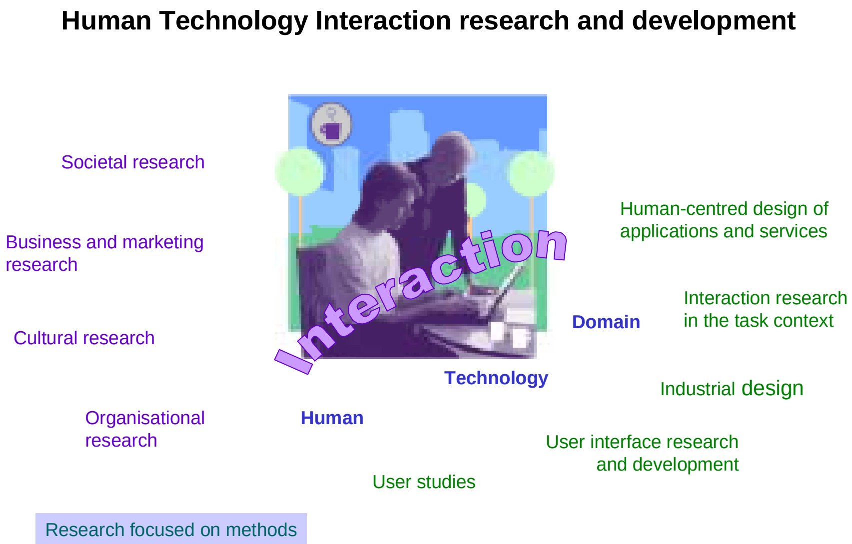

Figure 1. Different focuses of HTI research.

In our concept of HTI, the *environment* is considered part of the interaction. In Figure 1 the environment is represented as the *domain* of activity. The domain constitutes both an object of action and its specific context. The environment may be more or less artefactual. The features of the domain provide opportunities (affordances) for interaction, which must be comprehended and modelled in order to understand the content of the interactions. The *human-centred design of applications and services* deals with research and development that construct the artefactual human environment. *Industrial design* promotes the creation of objects and the built environment by developing functional and appealing forms and representations which convey social meaning through their style.

User studies focus on human beings in a more generic sense. They aim at defining the boundary conditions of mental processes and capabilities that are critical to acting in certain tasks. Such studies are typically accomplished in controlled experimental settings. User studies may also provide insight into the user's everyday life and information on their daily routines, likes and dislikes. The results of user studies may bring out ideas for new product concepts. *User interface* research is technology development focusing on interface solutions. *Interaction* research studies human capabilities, routines and practices of interaction in certain task contexts, and has strong emphasis on the tools and resources being used. Interaction is a co-operative process that is accomplished with the help of different communicative and operative actions.

Cultural and *organisational* research elaborates on the third level of human-technology *interaction*. On this level the attention focuses on values and rules, acceptance, individuals and groups, organisational structures and learning, management of systems, and so on. HTI research may and should be complemented by other research. *Innovation, business, and marketing research* helps us understand the dynamics of innovation processes and the economic dynamics of product development. *Societal research* tackles the global societal phenomena of information society. This area is very relevant because the actions and performance of individuals or groups form activity systems. An effective facilitation of their future changes requires that activities and technologies are viewed in a historical perspective.

2. HTI research and design traditions

As mentioned above, HTI research derives from two traditions: the cognitive ergonomics of transport and industrial applications, and human-computer interaction research. Due to the emergence of ICT as the generic technology in society, the two traditions appear to be converging. This provides theoretical challenges for HTI, as was recently noted by participants of the European Conference of Cognitive Ergonomics (Bagnara et al. 2003). The theoretical challenges were also highlighted in the ongoing roadmap project within the European framework under the topic of collaborative engineering workspaces (D'Cruz et al. 2002, Workspaces 2003). In the following we give a brief analysis of the past history of HTI from a theoretical and practical perspective, with the hope of gaining a better orientation towards the future.

2.1 HTI as a science of design

The core issues of HTI research is to improve the usability and appropriateness of tools so they can be embedded meaningfully throughout the cognitive system. HTI seeks to understand and support humans in their interaction with and through technology (Carrol 1997). Following from this general objective, HTI may be labelled a science of design. The multidisciplinary nature of HTI provides a persistent challenge for this science. HTI research should not only integrate between different disciplines, i.e. between the domains of specific engineering, electronics, information technology, mathematics, psychology, social sciences and philosophy, but also build bridges between theory and practice, design and use.

There are three core issues that every approach within HTI research has to tackle. The first is the conception of design, the second the conception of user activity – i.e. the user model – and the third the conception of interaction between design and use. The development of HTI research may be characterised as transitions in respect to these major issues (Carrol 1997).

The thoughts and design practices of a well-known industrial designer, Henry Dreyfuss, questioned the linear waterfall model of design (Dreyfuss 1955). He suggested that design is a piecemeal, specific, partial, iterative practice and must involve users. The idea of iterative design was adopted in HTI research. This radical attack on traditional thinking became normal practice in HTI research and development.

In the 1970s, the research focused on the problems of software development and human-computer interface design. The main research problem in this field was human-computer compatibility. In order to develop the usability of the computer and of applications, it was necessary to design the interface so that the underlying model of the system, and the model of it that the user developed through the interface, were as compatible as possible (Norman 1986). The concept of user activity, the user model, was an analogy of the computer. An information processing metaphor conceptualised human conduct as a generic linear processing of information from perception to action. This model resulted in defining user activity as conducting prescribed sequences of tasks. This is still a dominant approach in HTI research – naturally so, because the model is embedded in the basic assumptions of Western modes of thought. One of its fundamental beliefs is the Cartesian idea of a strict separation between the human being and his or her environment, or between mind and body. Information about something "out there" serves as a signal, and is processed in a linear manner in the human organism to provide an adequate response.

Current theories of cognitive psychology draw from the Cartesian tradition. They may be defective in describing or predicting the behaviour of the human operator in the context of the human machine interface. The reason for this lies in the history of cognitive psychology. This psychological approach was developed in close relationship with computational modelling. Eysenck and Keane, for example, call it the marriage of these sciences. In this theory formation the "real human components" (that is, the qualitative properties that distinguish a human from machines) might have been at least partly assimilated out, and are poorly represented in the theories of cognitive psychology (Eysenck & Keane 1990, Rämä 2001).

The prevailing user model also echoes the positivistic concepts of knowledge in Western science. This conception is in general qualified with the ideal of a detachment of the object of thought from the subject who is doing the thinking and acting, and from the concepts that s/he is using (Megill 1997). On a practical level it became evident, however, that learning and problem solving were not sufficiently understood within the prevailing user model and the information processing paradigm. As a reaction to this, an opportunistic solution emerged, which was conceptualised in the "active user" or "user improvisation" approaches.

As a reaction to the lack of control and to the inefficiencies of user improvisation, an important question was posed with regard to the nature of iterative design (Carrol 1997). The problem was whether the iterative design is more than learning from experience. Consequently, various new concepts in HTI were developed in the 1980s. They may be interpreted as attempts to make design more rigorous than a spontaneous experience. One expression of these attempts is the pressure to develop explicit usability specifications (ISO-DIS-9241-11 1998). A further consequence relates to the need to broaden the empirical scope of user studies. As a result new methods were developed, among them approaches like user-centred design, participatory design, field studies, contextual design, and ethnographic research. The focus areas and methods of these approaches from the perspective of studies of mainly office-type work are listed in Table 1 (Kujala 2002).

Table 1. A comparison of different HCD approaches (Kujala 2002).

	User-centred design	Participatory design	Ethnography	Contextual design
Emphasis	Usability	Democratic participation	Social aspects of work	Context of work
Typical methods	Task analysis Prototyping Usability Evaluations	Workshops Prototyping	Observation Video analysis	Contextual inquiry Prototyping

In coherence with the attempts to make user studies more rigorous, emphasis was also devoted to the cost-effectiveness of usability testing. The development of the usability engineering tradition (Nielsen 1993) is an expression of this aim.

The relationship between design and usage is the third important issue of HTI. A review of recent relevant literature by Kujala (Kujala 2002) showed that early user involvement appears to affect user and customer satisfaction directly, by providing the possibility to participate. This effect appeared, however, to be mainly indirect. Thus user involvement enhances the system quality by first improving the quality of requirements, which in turn leads to higher user satisfaction. The results concerning the effects of product development on economical efficiency and time effectiveness were found to be contradictory. Specifically, major difficulties appeared in communication between designers and users and in the exploitation of user knowledge in the design process. To improve the understanding of the demands of usage, far more comprehensive studies should be carried out in real situations. This would facilitate the understanding of user practices (Lanzi & Marti 2002).

The contextual design tradition offers one solution for comprehending and defining user practices. This tradition emphasises the significance of clarifying the task context, including the stated goals and conditions of action. It provides elaborate tools for analysing these contexts as domains that put constraints on user actions and, hence, should be considered in the design of tools for these actions. The strength of the contextual design approach is that it shifts the focus from the design of technical products or services to the construction of new ways of working. The founders of the contextual design approach stated that user studies should not be considered as a straightforward process of gathering or eliciting user data. Instead, it should be emphasised that designers must learn to infer what this information means for design (Beyer & Holzblatt 1998, Savioja 2003). Beyer and Holzblatt assessed that making design more user-centred requires improvement not only in the users' abilities to participate in the design process, but, also, in the designers' own ways of thinking and working.

The computer supported co-operative work (CSCW) is a tradition in the HTI research that has had a major impact in redefining the user model and it also has shed light to the relationship between design and use. The CSCW tradition has a divergent theoretical background but is characterised through a strong ethnomethodological orientation (Bannon 2002). Methodologically, CSCW draws from phenomenology but also from the cultural historical theory of activity (Bannon & Kuutti 2002, Leont'ev 1978, Vygotsky 1978). The seminal work in this tradition was the book titled Situated Action by Lucy Suchman (Suchman 1987). In this book the author convincingly demonstrated the drawbacks of interpreting human conduct as being a sequential course action that results from following a predetermined action plan. She suggested the conception of situated action that acknowledges the constructive situation specific structure of action and claimed that plans are but weak resources of situatively constructed action.

Many of the concepts introduced by the CSCW approach have been adopted in the vocabulary of the current HTI research and development. It has been claimed, however, that concepts that originally signified theoretical attempts to reformulate the user model are now utilised in an insufficient and superficial way (Bannon 2002, Carrol 1997). Consequently, these important theoretical notions are reduced to new labels for old ways of thinking. For example, the notion of *context* denotes the idea that action and thinking must be understood in and through the circumstances in which it takes place, and that the environment is objective through the subject's constructive action (Järvilehto 1994, Megill 1997). However, in the HTI community the term is typically used in an objectivistic way. Thus, "context" is comprehended as something "out there" and given. Thus it appears, falsely, that the context may be defined in a simple way, and that the machine could be able to do the definition. This may, however, succeed only in a very restricted sense.

It is also commonplace for the concept of *awareness* to be considered from an objectivistic perspective. Hence, awareness is equalled with recording the stimuli in the environment. The intentional and purposeful nature of the subject's actions and the role of practical operations in the formation of the interpretation of the state of the world are neglected. The cycle between perception and action produces interpretation of the environmental features with regard to their relevance to the ongoing activity and the desired results (Norros & Klemola in press). The concept of *intuitive* is a further frequently used notion in HTI research. The concept is linked tightly to the new trends of conceiving human action as embodied in the environment, and intentions and rational forms of behaviour being the function of the whole human body, not only that of the brain (Ingold 2000). Habits that signify the continuity of action in a changing world are dispositions to act and involve learning of new scaffoldings into the cognitive structure of action within a culture. *Smartness* is an attribute of such a distributed cognitive system. Habit are shared in communities of practice (Wenger 1998) and enable making use of the environment in an intuitive way.

The practice-relevant consequence of a non-reflective use of terms is that unrealistic expectations with regard to technology may emerge. If theoretical distinctions are not made, but instead concepts are adopted without understanding the theoretical motivations, human features are attributed directly as desired qualifications of the new technology. This easily results in an unintended technocratic attitude that tends towards the substitution of human action for technology. The unintended consequence may be that people experience a threat of losing control of their tools. A realistic point of view of technology development that is capable of producing significant changes in practices would rather adopt a target to improve the whole distributed cognitive system (Hollan et al. 2000).

2.2 Human-centred design as a design policy

It was indicated above that making the iterative design more rigorous was felt necessary in order to control the design process better and also to improve the empirical scope of user studies. As an expression of these aims, a collective effort was organised for defining a standard guideline for an iterative design process that would express a user-centred aim. The Human-Centred Design standard by the International Standardization Organization (ISO-13407 1999) was a concrete and important step towards integrating the human-centred design approach into the existing product development processes in practice. The human-centred approach was also advocated in the standards recently defined for the design of complex information and control systems (ISO-11064 2000). The design processes of ICT systems are typically very extensive. Several testing and evaluation phases must be included to control fulfilment of the demands of usage.

According to these ISO standards, the incorporation of a human-centred approach is characterised by:

a) active involvement of users and clear understanding of user and task requirements,

b) an appropriate allocation of functions between users and technology

c) the iteration of design solutions (Figure 2)

d) multidisciplinary design.

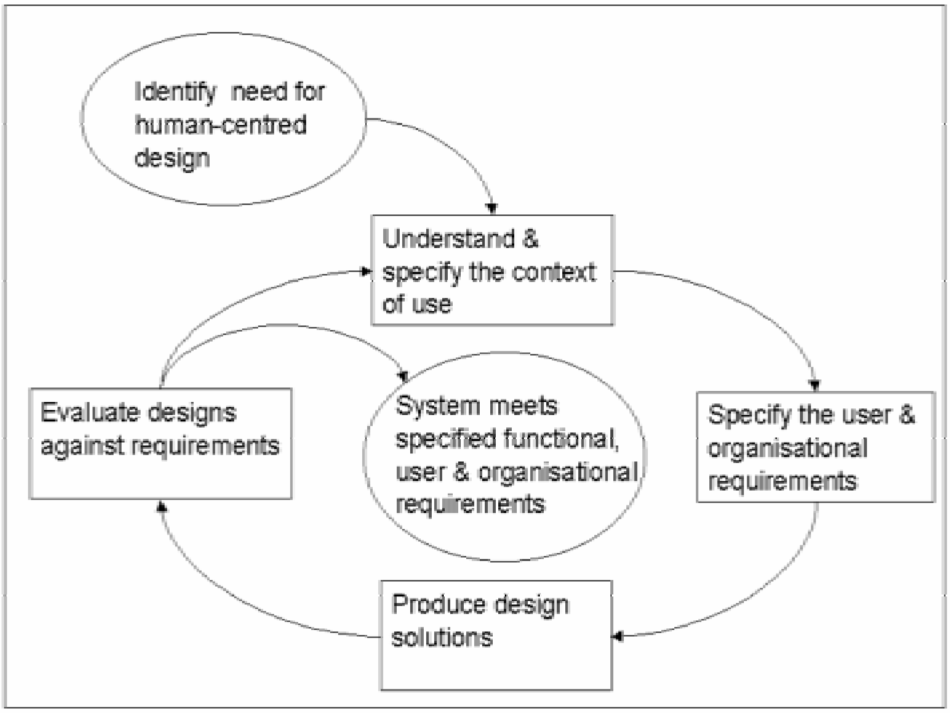

Figure 2. Human-centred design process as defined by ISO 13407.

ISO13407 has provided a valuable framework for multidisciplinary design projects by defining both how to organise the design project and how to carry it out in practice. The standard is best suited to situations where a concrete product development is ongoing. The standard – similar to much other HTI work – is mainly targeted at work-oriented applications. In consumer applications, e.g. organisational requirements must be interpreted more widely. Similar to quality systems, organisations should commit to human-centred design policy. Through this policy, Human-Centred Design becomes embedded in the organisation’s culture and happens naturally as a part of any design process.

Thoughtful, iterative design and evaluation enable the exploration of several design alternatives. *Design rationale* is the reasoning associated with the design, describing why certain design decisions were made, by whom and when. Design rationale presents clearly not only the decisions made, but also the alternatives considered and the reasons for accepting or rejecting them. Design rationale was originally adopted in process industries. In this field the design rationale improves the economic, safety and environmental performance of processes. Design rationale is a vital part of the knowledge of any company (Karsetsky 1996).

Contextual Design (CD), described earlier in Chapter 2.1, is an important design approach that enhances the design focus from the tools to be developed to the work practises of users, so that the systems to be designed will fit the real use (Beyer & Holzblatt 1998). CD was first introduced for the design of work-related applications. The idea is that the whole design team has a good understanding of the users, their tasks and the contexts of use, and that the users participate the design throughout the process.

CD has also been adopted in the design of consumer products where the usage contexts vary a lot, and may even change during usage (Väänänen-Vainio-Mattila and Ruuska 2000). Contextual Inquiry (CI) provides a structured and manageable method for gathering in-depth insight into users' or potential users' work context and life in general on selected focus areas. CI has proven especially useful in discovering people's personal ways of organising their tasks. The CI method also serves as a tool to produce design ideas and background for requirement formation based on vast amount of qualitative data, thus being useful in concept design.

The application of the principles of Human-Centred Design have high payoffs (INUSE project document: User Centred Design 1996): Reduced production costs, reduced support costs, reduced costs in use and improved product quality have been reported. Human-centred design results in products that have a higher quality of use and are more competitive in a market that is demanding easier to use systems. The complete benefits of human-centred design can be determined by taking into account the total life-cycle costs: conception, design, implementation, support, use and maintenance (ISO 13407 1999).

The effect of user involvement on the system quality and user satisfaction is a complex and contradictory issue (Kujala 2002). The positive effects of user involvement in design do not become evident in a very straightforward way, and the positive experiences and actual benefits in practice do not necessarily manifest themselves in the scientific literature. It should be beneficial for the practice itself to reflect critically on the actual effects of the methodology. Further improvements are needed in the methodologies applied in user studies. Contextual design and ethnographic methods will be important tools in future HTI research. The distributed cognition approach or the activity theory are also promising approaches. Creating a real understanding of user actions and of the role of artefacts in action requires scientifically-oriented, profound research. A concern for scientific orientation in HTI studies was expressed recently by Francis Jutand, who listed this as the first challenge of the design projects for smart objects (Jutand 2003).

3. State of the art at VTT

In an analysis of the research needs of the knowledge society, Tuomi defined three broad areas of activity that are relevant to this research (Tuomi 2001). They are everyday life, systems of production (in which we place work and working life) and institutions and culture. VTT has an established role in the research of new technologies and in the facilitation of application of technologies in enterprises. VTT also plays a role in developing socio-technical infrastructures, and acts as an expert organisation for the national authorities in various fields of everyday life and production. As a result, VTT has already developed HTI research in all three of the above-mentioned domains. Moreover, new interesting topics for research are expected to emerge, particularly in the cross-sections between these traditional domains (Tuomi 2001). By virtue of its interdisciplinary nature, VTT is in a position to act effectively in these merging areas.

In the following we describe current research approaches to HTI in four different research units at VTT: VTT Building and transport, VTT Electronics, VTT Industrial Systems and VTT Information Technology. We found that about 70 research projects could be linked to the HTI theme. The content and nature of these correspond to the research traditions and application domains of the hosting units. The unexpectedly high number of HTI-related projects was interpreted as a sign of increasing demand in this field, and an indication of the need to articulate the HTI theme as a strategic topic.

User needs, usability, utility, acceptability and impact analyses are all issues that emerge with regard to the implementation of ICT appliances in everyday life. Thus in recent years research in this area has continued to grow at VTT. It would be of great advantage to the future development of all HTI research at VTT to ensure that this attractive area of research does not fall into a void. There is a long research tradition at VTT in HTI issues relating to human behaviour and decision-making in complex, safety-critical work activities and transportation systems. VTT also has experience from human error studies and accident analyses in these domains. In order to make explicit the traditions on which the present HTI research may draw, we have included a brief description of the behavioural science traditions and approaches at VTT in Chapter 3.5, based on a report prepared by the VTT strategic theme *Safety and Operability*.

In the following descriptions we use the graph introduced in Chapter 1.2 to describe the main focal points and methods of research in the four operating units of VTT.

3.1 Human Factors Studies at VTT Building and Transport

This summary reports on ongoing or recently completed studies in four research areas at VTT Building and Transport (RTE). Specifically, the research areas are (1) Transport and Logistics and (2) E-Knowledge Society and Teleactivities, (3) Structures and Building Services and (4) Wood technology.

Transport and Logistics

Road and traffic is a technical system, and there is a long tradition of studying road users' interactions with it. Typically, the system is available to every citizen, including children, the elderly and the disabled. In many cases the approach is social and related to social policy. In new HTI research the focus is on human interaction with Intelligent Transport Systems (ITS). This research is mainly conducted by the Transport Telematics group and Traffic Safety group (Figure 3).

HTI research by the Transport Telematics group covers both the interactions between the driver/operator, the vehicle and the environment, and user acceptance (Figure 4). We typically analyse human machine interfaces that must be designed such that users can operate the system easily and without increased risk to traffic safety. Research methods cover automatic registrations of driver behaviour, observations and interviews.

For user acceptance we specialise in the analysis of user needs and requirements in several areas of transport to support the development of socially advantageous transport systems. The principal research methods cover interviews, surveys and group discussions. As the systems become more complex, it may be essential to evaluate how well the user understands the operational and management principles of the system. In the case of implemented systems, the amount of use and willingness to pay may be of interest.

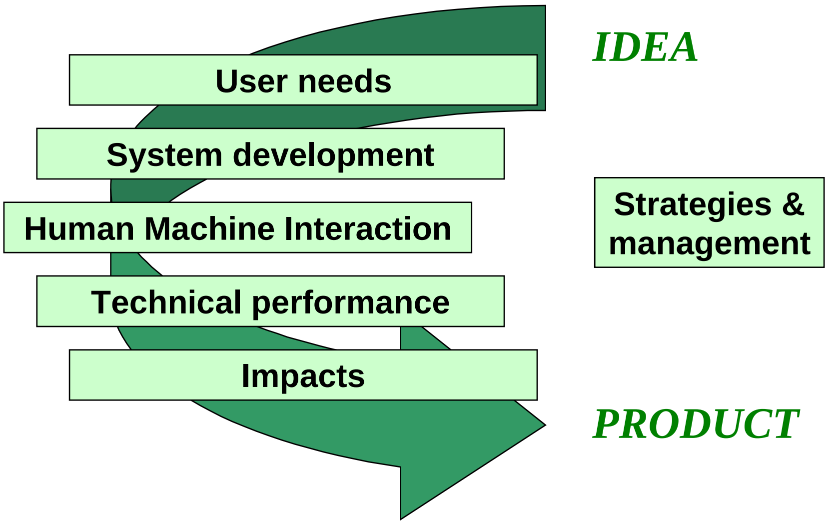

Figure 3. HTI research and development at VTT Building and Transport: Transport and logistics.

E-Knowledge Society and Teleactivities

Research topics include how modern ICT applications support living, working and mobility in the information society. User needs were mapped in order to provide services that bridge the gaps in opportunities or abilities to use telecommunications services. Other topics look at how to promote the welfare of humans, communities and the environment in a new deal between housing, work and mobility in urban form. Special challenges arise when teleworking is introduced as a mobile way of working, as in one case study where teleworking on the train was included as part of the personnel strategy of an organisation.

User needs and experiences of the benefits and drawbacks of teleworking from home have also been analysed. Special emphasis has been placed on designing a home office based on real and diversified user needs in a new block of flats, together with designers, researchers and in-moving residents. Self-documentation and participatory design methods were applied and reported in detail while still in progress. Also various solutions of ambient intelligence embedded in the field of housing have been analysed.

The idea of a home equipped with technical burden-reducing and life-enhancing devices is an old one. What is new is the added value of the transparency and interactiveness of ambient intelligence. The technology should enhance the quality of life of residents, not only by facilitating their daily activities, but also by supporting their socialisation. Another major challenge for ambient intelligence is how to make technology learn about the people and their identity: habits, preferences, behavioural patterns etc. and how to apply such knowledge in varying contexts. The ultimate challenge is to promote ambient intelligence in balance with producing a high quality technological system of life-enhancing "housing-aids" and providing enough safety, stimulation and socialisation for the residents.

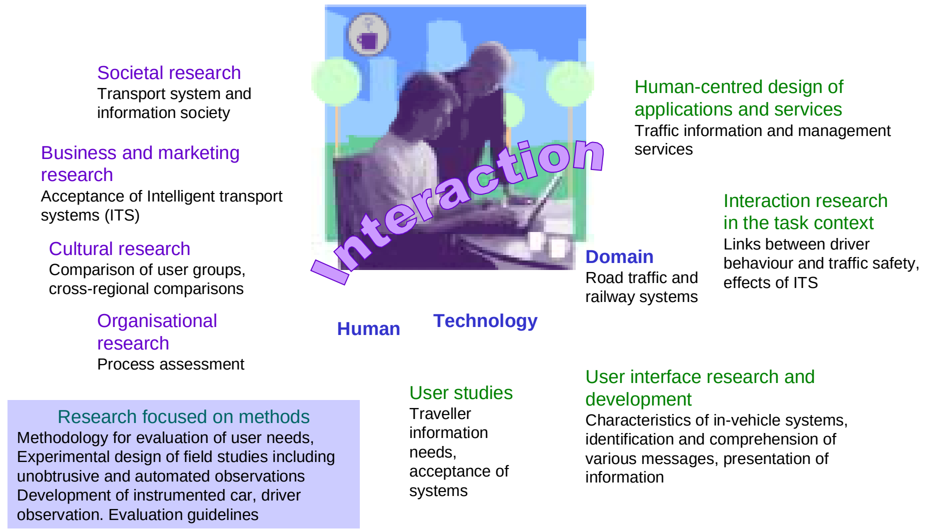

Figure 4. HTI research at VTT Building and Transport: Transport and logistics.

Structures and Building Services

The Technology Integration Group and Technical Building Services Group are developing a general approach for modelling integrated services in smart environments (Fig. 5). The group's particular areas of expertise, and therefore the main focus of the work, are home and office environments. In addition, piloting and dissemination of research results to potential user groups provides a platform for gaining more understanding of user needs.

In future, only eco-efficient solutions will be acceptable. Sustainable development and development of a knowledge society go hand in hand. Lifetime performance of the built environment must be verified. Performance-based building places both user and owner needs in the spotlight. The methodology provides practical means for assessing the benefits of new technologies.

Visions of a knowledge society tend to emphasise increased intelligence of buildings (living and workplaces). Attractive, credible and realistic models in relation to service are then developed. Technology modules comprise (i) a healthy environment, (ii) a functional community structure, and (iii) new technologies and incentives.

There is a need to develop concepts for new product innovations and systems innovations to make home services in multi-storey residential buildings easier – and possible. The key issue is integrating existing and new buildings in the global e-commerce network by providing logistics solutions for multi-storey and other buildings. Development of new business models in service networks is expected to generate impulses for growth in traditional building sector business activities, such as rehabilitation and modernisation.

Wood technology

Models and software systems are developed in order to provide decision-supporting tools for the procurement of wood raw material, and the production and marketing of wood products. Software tools are commercially available. About 30 sawmills and other wood companies, among them the biggest in Europe, use software in their daily business and not only for strategically planning operations. Software tools are provided with traditional interfaces. There are problems with too many input tables, simultaneous running of results from different software, not enough graphics, self-learning options etc.

Machine vision systems are used for automated measurements of the properties of wood raw materials and final products. Data and information provide the fundamentals for evaluation and grading of pieces and the optimisation of cutting procedures. Increase of the value yield over that obtained with manual grading may be very high. However, vision systems are complex to use because so much reliable data is needed. It is also difficult to change the grading rules due to the large number of parameters affecting the result.

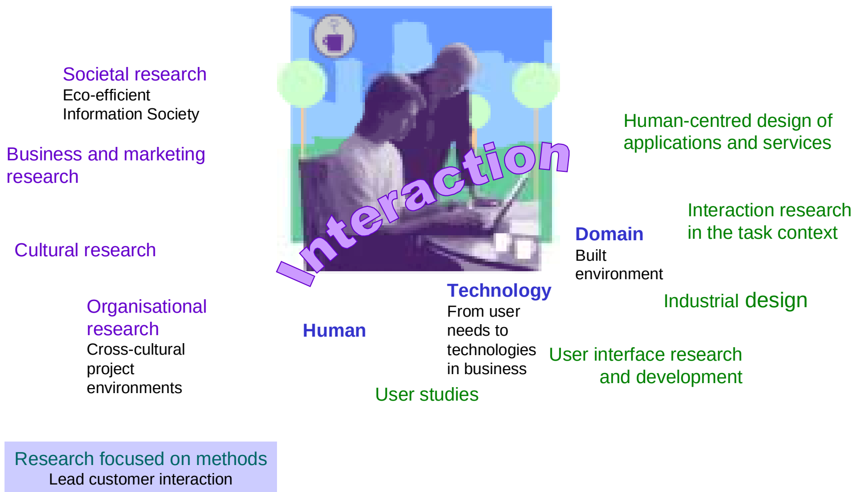

Figure 5. HTI research at VTT Building and transport: Structures and buildings.

3.2 Research on Enabling Technologies at VTT Electronics

VTT Electronics has a broad scope of research topics that deal mostly with hardware and software issues in industrial and embedded systems. The emphasis has in recent years shifted from industrial applications to consumer electronics and their applications. Therefore not only HTI in a factory environment, but also in everyday environments, mostly via handheld wireless devices, has become the focus of attention. Research at VTT Electronics is concerned mostly with the technology side of HTI, not so much with the human factor. The human component is taken into account in the requirements specification phase of projects and in the evaluation of the final research. The technology component looks particularly at enabling technologies for interaction.

The main research topics of VTT Electronics and some results are briefly described in the following paragraphs (see also Figure 6).

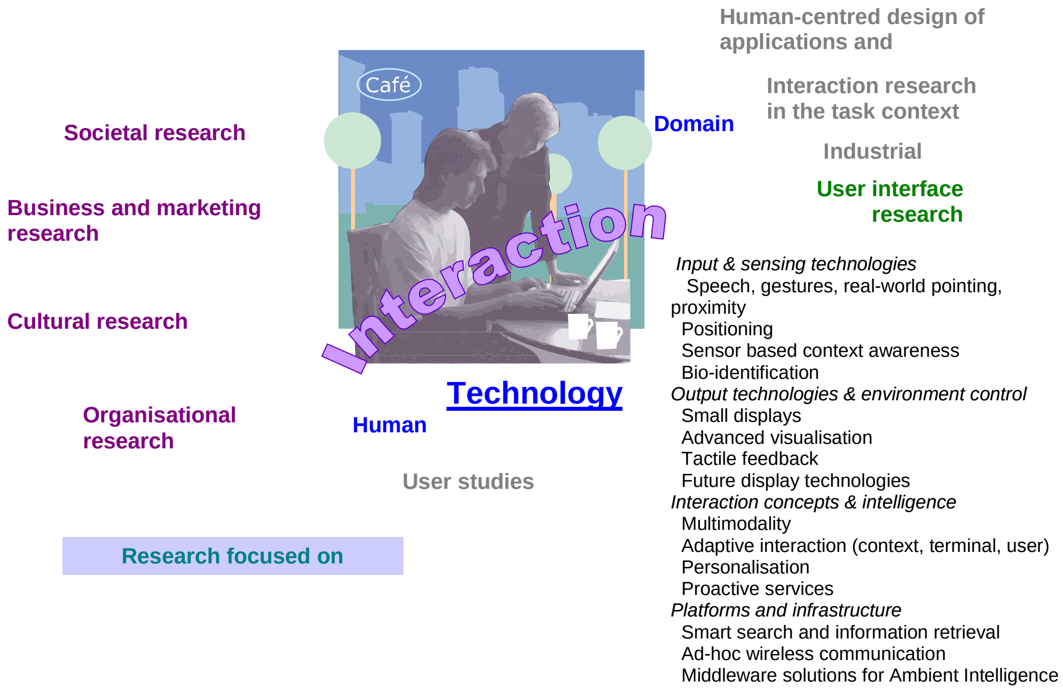

Figure 6. HTI research and development at VTT Electronics.

Input technologies and sensing

Low-power wireless sensing technologies and infrared communication technologies have been developed for ambient intelligence applications (ACM 2003)). Sensors have also been packaged together with RF communication technologies for the same purpose, resulting in the so-called SoapBox (Sensing, Operating and Activating Peripheral Box for intelligent environments). SoapBox is a matchbox-sized prototype that includes accelerometers, a compass, a light sensor and a proximity sensor (based on IR). These boxes can communicate via a proprietary short-range wireless communication protocol (RF). The boxes have successfully been used to build several ubiquitous computing applications utilising the boxes' features. The boxes have also been enhanced for realising pointing functionality and haptic feedback. The low power consumption makes it possible to use the boxes for up to several years with a small button-sized battery for e.g. periodic wireless measurements (Tuulari & Ylisaukko-oja 2002).

Extensive research in establishing context from sensor input, as e.g. obtained by means of SoapBoxes, as well as the use of context in applications has been performed, utilising a variety of inputs (Tuulari 2000; Keränen et al. 2003; Korpipää et al. 2003a; Korpipää et al. 2003b; Mäntyjärvi & Seppänen 2003).

Other work related to context awareness has been done by analysing audio-visual signals. Based on an early implementation of a speech-recognition system for the Finnish languages (Peltola et al. 1999), recent work has included audio signal segmentation (speech/music, multiple speakers) and indexing (Penttilä et al. 2001), environmental noise analysis, and the efficient and scalable encoding of audio signals. Future research may include biophysical signal analysis for e.g. affective computing applications.

The SoapBoxes have also been used for research in novel user interfaces and positioning techniques. For example, a methodology for step-based positioning utilising the SoapBoxes was developed (Vildjiounaite et al. 2002). More conventional positioning techniques were also implemented, e.g. utilising the field strengths of WLAN base stations (Haataja 2001).

The SoapBoxes have further been used for the implementation of gesture recognition. Both tilting gestures and simple taught gestures can be used to control applications ranging from home appliances, maze games, virtual design studios (Giugiaro, Italy) and scrolling maps, to dice (Kallio et al. 2003, Vehmas et al. 2003). Many of these applications were built in the Ambience project[1], and aim to realise the Ambient Intelligence vision (Van Loenen 2003). The proximity sensor in SoapBoxes has further been used for two-handed interaction for zooming purposes (Rantakokko & Plomp

[1] http://www.extra.research.philips.com/euprojects/ambience/

2003). Similar boxes that have been used in the European Smart-Its project have been enhanced to e.g. recognise their travelling together by analysing the movement of the boxes (Vildjiounaite et al. 2003). Future interest involves e.g. the use of pointing to select tagged physical objects in the environment for interaction (Ailisto et al. 2003a).

Output technologies and environmental control

Control interfaces for work vehicles were developed as part of the research in mechatronics. In addition to on-board control, also wireless technologies have been applied to realise remote control for robots and aid drivers' task and information management by means of wireless technologies.

The optoelectronics research field performs research related to emerging display technologies realised by e.g. OLED technologies. The PRINTO project investigates, evaluates and develops volume-scale fabrication methods for optics, electronics and optoelectronics and materials suitable for those. Manufacturing methods under investigation include: gravure, flexo, off-set, ink-jet, and hot embossing. The main application areas for components and modules to be fabricated are disposable packages and printed matter. Furthermore, the optoelectronics research field has developed advanced optical measurement systems for industrial use.

Interaction concepts and intelligence

Adaptive interface technologies, allowing automatic adaptation to terminal features and available modalities, were studied and applied to e.g. home environments. A generic User Interface description format and adaptation methodology has been developed for the control of home appliances by means of different sized desk-top and mobile graphical user interfaces as well as speech-based interaction (Plomp & Mayora-Ibarra 2002, Plomp et al. 2002b).

Development of proactive services is a long-term topic of research, requiring both advanced interaction technologies and a significant amount of intelligence – methods that make decisions based on context and adapt services accordingly (Rantakokko and Plomp 2003, Korpipää et al. 2003, Vildjiounaite et al. 2003, Mäntyjärvi and Seppänen 2003).

Platforms and infrastructure

Architectures, middleware and wireless solutions have been developed that particularly aim to realise the Ambient Intelligence vision. These solutions provide support for the management and discovery of services, ad-hoc connections, embedding intelligence, adaptive interaction and wireless as well as wired connectivity. These solutions have been used in several projects to construct prototypes that demonstrate applications of Ambient Intelligence. The applications were developed for home environments, public environments (shopping mall) and mobile users (Plomp et al. 2002b, Keränen et al. 2003).

3.3 HTI studies in complex high-reliability work at VTT Industrial Systems

HTI is a socio-technically oriented strategic focus area at VTT Industrial Systems. Its mission is to promote the implementation of technical innovations by encouraging their meaningful use in industrial practice. By means of participatory analyses and evaluation of user practices and cultures, we aim to facilitate development processes in industrial communities and organisations. VTT Industrial Systems has over 20 years' experience in the study of issues relating to human factors in high-reliability organisations. Practical tools have been developed for the analysis of human error, accidents and incidents, and for the evaluation of normal working practices, organisational culture and management. In interaction with the international human factors research community, a systemic methodological approach, the Core-Task Analysis (CTA), was created for the analysis of work. The basic structure of the methodology and its implementation are depicted in Figure 7.

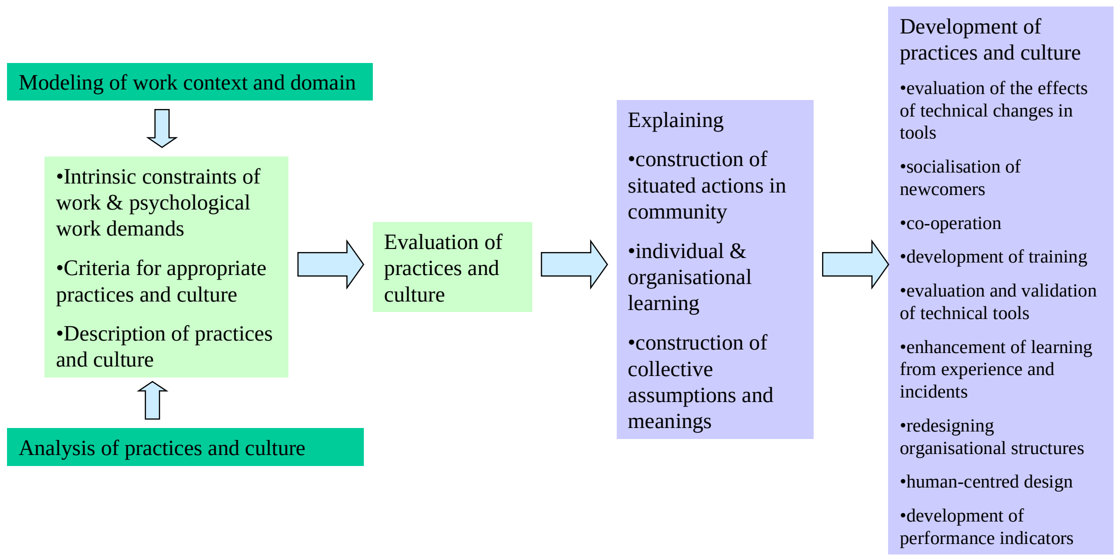

Figure 7. The implementation of Core-Task Analysis and application of results.

The CTA methodology is used and developed further in the studies that focus on three main areas:

Activity-centred design and system usability

The research focuses on creating concepts and methods for activity-centred design of smart devices and environments, with the aim of improving the system usability of complex artefacts. The new concept of system usability is under development in research projects focusing on the design and validation of large information and control systems, such as maritime traffic control systems, nuclear power plant control rooms, or paper and pulp processes. Our analyses also tackle other expert activities such as anaesthesia or air traffic control, in which ICT-based tools are used for monitoring dynamic events. We also analyse interfaces of the cabins of movable machines and vehicles.

Analysis and evaluation of working practices

A further line of study is the analysis of operators' interaction with the dynamic, complex and uncertain environment and their co-operative practices. Utilising the Core Task Analysis methodology, research is conducted in natural work situations and in simulated situations. We also participate in accident and incident analyses.

In connection with operator studies, work is being done on the problems of learning at work. Simulation-based learning environments are designed for developing the operating skills and conceptual knowledge of personnel. Simulations also provide possibilities for the collaborative design and development of user interfaces. Also being studied are organisational practices for better knowledge management in learning organisations. Pre-requisites for new networking practices are being created in developmentally oriented studies in small and intermediate manufacturing industries.

Organisation and culture

The third area of HTI research deals with organisational culture and practices in high-reliability work. The research focuses on developing new methods with the aim of combining survey-based measures of organisational culture with particular domain-specific evaluations of organisational culture and working practices. The latter are behavioural expressions of culture. The Core-Task Analysis methodology is combined with a method for contextual analysis of organisational culture (CAOC).

Figure 8 elaborates main areas of HTI research at VTT Industrial Systems.

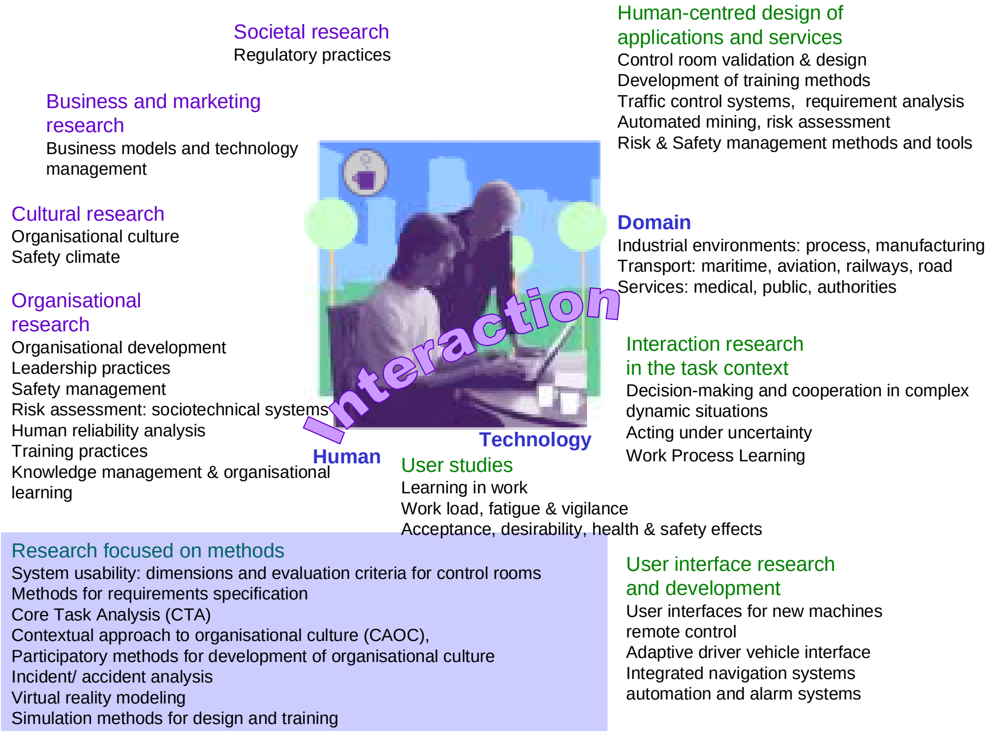

Figure 8. HTI-research at VTT Industrial Systems.

In the above description we have focused on HTI studies that have a strong orientation towards behavioural science. As indicated above, human factors research is an established focal area of research at VTT Industrial Systems. It should be noted that within the Industrial Systems unit there is a considerable amount of engineering research that has direct relevance for HTI issues but is not considered at length here. Interdisciplinary HTI-related research is carried out in cooperation with the following other focal areas of the unit: System Dynamics and Simulations, Production Management, Intelligent Systems and Services, Future Machines, Future Factory, and Safety and Operability.

3.4 Human-Centred Design at VTT Information Technology

At VTT Information Technology HTI research has strong connections to technology research and development. The typical way of working is to form multidisciplinary project teams where human technology interaction experts are in charge of adopting the human-centred design approach. The outcome of the research projects typically includes technical prototypes and the results of usability studies that point out factors affecting user acceptance of the technology.

The human-centred design approach is based on the ISO 13407 standard and is characterised as follows:

- The user's point of view is presented from the very beginning and throughout the project.
- User evaluation activities are scheduled; typically we evaluate scenarios, mock-ups and prototypes with users. In most projects, the final prototype is evaluated in a medium- or long-term field trial to get feedback on usability and utility in everyday use.
- The whole research team is responsible for producing technology that is usable and useful. The project team analyses the results of the evaluations together and makes decisions on necessary changes for the next iteration cycles in the design.
- Usability evaluations are also a learning process that can be concluded as usability design guidelines for specific technologies, application areas, user groups etc.

The research focuses mainly on consumer applications in the fields of mobile systems, ubiquitous computing, media technology and novel user interfaces (Figure 9). Within these fields adaptiveness, context-awareness, personalisation as well as multi- and cross-platform services are common research themes. Usability studies are often complemented by studies on usage cultures and studies on business models. Our aim is to adopt a design-for-all approach by involving different user groups in the design and placing special emphasis on those user groups for whom the technology might be especially useful.

In addition to usability studies and human-centred design in individual projects, we have identified a need for wider user and usability studies. These studies have been realised as horizontal usability projects, e.g. as part of technology research and development programmes. Another trend is to extend human-centred design to earlier phases of technology development. This includes e.g. human-centred design of microelectronics and -sensors so that users can really affect how and where these technologies will be utilised.

The aim of our research on intuitive user interfaces and services is to look for natural and novel ways to use computer technology. One of the basic challenges and starting points is replacing WIMPs (Windows – Icons – Menus – Pointing devices) and designing alternative new user interfaces. The research includes both technical user interface development and research of new design methods for novel user interfaces. The research focuses on user interface technologies, more specifically on interfaces for ubiquitous computing as well as bodily and spatial user interfaces.

The research infrastructure at VTT Information Technology includes:

- A usability laboratory
- A studio for development and evaluation of bodily and spatial user interfaces
- A field test environment for wireless services (WLAN) in the centre of the city of Tampere (Tampere Research and Evaluation Laboratory, RELab).

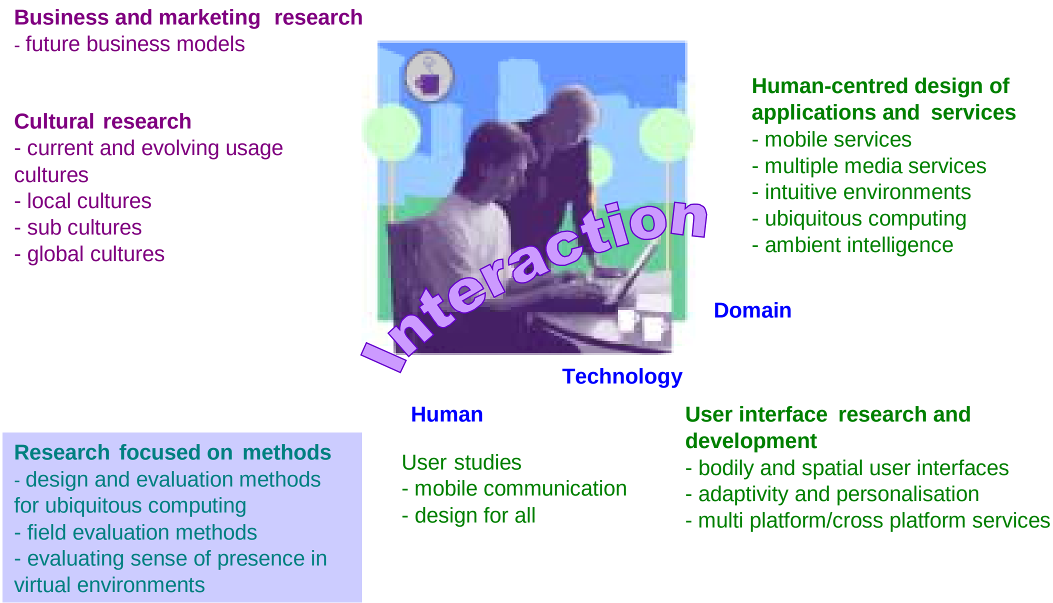

Figure 9. HTI-research and development at VTT Information technology.

3.5 Approaches in behavioural sciences in VTT research

At VTT there are long traditions of research into human behaviour in several areas and domains of study. The origin of human factors research at VTT was safety-critical domains and applications. Later on, new criteria like comfort, efficiency, fluency etc. became more important. Research of consumer applications focuses on user acceptance, based on perceived ease of use and utility.

A review by Rathmayer and Rämä identified six research groups at VTT that conduct research in the behavioural sciences. These were the Traffic Safety and Transport Telematics groups (VTT Building and Transport), Human-Centred Design and Intuitive Environments groups (VTT Information Technology), and Production Risk Management and Human Factors groups (VTT Industrial Systems) (Rathmayer & Rämä 2003). The research covers several domains including traffic and driver behaviour, mobile systems, new media, user interfaces, intuitive environments, risk management in production, safety of production systems, dynamic complex industrial systems, nuclear power plant control rooms, maritime traffic control systems, anaesthetists' utilisation of patient monitoring systems etc.

The behavioural scientist groups at VTT have so far worked quite independently of each other. There are both common features and differences in their approaches. A common feature is close co-operation and interaction with domain-specific engineering disciplines and a strong tradition of conducting field studies. In a general review, the groups also appear to share common methods of data collection such as interviews, questionnaires and observation techniques.

However, all six groups differ in their choices of theoretical bases, and consequently a more detailed analysis of methodologies would probably reveal differences as well. The main reason for the different theoretical approaches is the domain-specific motivations connected to the research objects. Personal interests and backgrounds contribute to these choices. However, our knowledge covers a broad area, and the possibilities to synthesise and develop this knowledge should be explored (Rathmayer & Rämä 2003).

The theories applied concern engineering psychology, cognitive operations, information processing, motivation and risk compensation, cityscapes, user cultures, user acceptance of information technology, system accident analysis models, risk management and dynamic society, activity theory, cognitive work analysis, organisational culture and leadership, decision making, and human error. The repertoire is also very broad methodologically from case studies to quasi-experimental field studies and surveys. Both quantitative and qualitative methods have been used (Rathmayer & Rämä 2003).

4. Societal drivers for HTI

4.1 Stronger focus on users and usage

The reasons for considering human factors of technology were first related to the reactive protection of the safety and health of workers. The development of safety science and safety-informed design has enabled a proactive approach to industrial and environmental safety. In this context the notion of human error has been dominant. Human error was first treated on an individual level but later the insufficiencies in action were set into a more global system-level context. Organisational strategies for management of safety have recently been adopted (Hollnagel 2002, Reason 1990).

The health, safety and reliability problems questioned some of the positive expectations that were placed on the mechanisation and automation of production. Later, concern over the effects of advances in technology on the immediate environment and on the whole ecosystem emerged. These critical considerations introduced a further, much more global concern with regard to the development of technology.

Today ICT applications are implemented at a fast rate. As a result, solutions provided for the market are not always fully developed, and people have not had the chance to create practices and skills for mastering the new devices.

The development of information society was earlier understood to be an economic issue, and technology to be the driving force that made economic growth possible. This traditional ‘technology push’ view has been criticised by the European high-level-expert group (HLEG 1997), which pointed out the insufficient focus on the needs of people in the information society. Tuomi names ‘the user’ as a missing link in the chain of socio-technical evolution: “Users are not only passive consumers of technology (Tuomi 2001). They are active producers who make technology meaningful in their everyday life, often in ways that surprise engineers, entrepreneurs, and policy makers.” Also other authors have pointed out that creating meaningful usage has become an important factor for the economical success of technological innovations (Hasu 2001). The use of new technology has spread slower than expected by the technology developers. To enhance the development of information (or knowledge) society, the importance of the social context and the human dimension of technology should be emphasised.

4.2 Information society for all

The concept of information society is wide and includes several definitions. The revolution of information technology, new global economy and networking are generally understood as aspects of this phenomenon (Castells & Himanen 2001). Webster presented five definitions of information society which are technological, economic, occupational, spatial and cultural (Webster 1995). Changes in work have been one of the most popular measures of the information society. The changes relate to the content of work, the organisations, and the use of time and space. The concept of information society defines the social, economical and functional context of HTI research. It describes the use of technical innovations in the society and defines the challenges and trends that are relevant and important to react to in HTI research and design. The concept also highlights the welfare of the whole society besides that of individuals or communities.

Castells and Himanen tried to raise the discussion about values in information societies by comparing development in some countries. The authors claimed that the Finnish model has many advantages and positive features over those in some other countries, e.g. the support of public decision making, the high quality education system and equality in the society.

The Advisory Board for Information Society in Finland has identified several future challenges with regard to extending information technology to all user groups in the society. These are: exploiting new technology in the economy; delivering services to all citizens; improving knowledge; developing contents production, electronic services, electronic identification, utilisation of information and communication technology in the public sector; development of mobile technology; and improvement of security and international projects (eEurope) (Advisory Board for Information Society in Finland, (Neuvottelukunta 2002). As information technology products are increasingly targeted to the general public, it becomes essential for all user groups to be taken into account in the design. The Association for Computing Machinery has made a visionary commitment to universal usability through its code of ethics: "In a fair society, all individuals would have equal opportunity to participate in, or benefit from, the use of computer resources regardless of race, sex, religion, age, disability, national origin, or other such similar factors." (ACM 2003).

The requirement for universal access stems from the growing impact of the fusion of emerging technologies, and from the different dimensions of diversity, which are intrinsic to the information society. These dimensions become evident when considering the broad range of user characteristics, the changing nature of human activities, the variety of contexts of use, the increasing availability and diversification of information and knowledge sources and services, as well as technical platforms.

The European Design for All e-Accessibility Network (EDeAN) defines eAccessibility as follows:

"The term 'eAccessibility' stands for the access which new Information and Communication Technologies (ICTs) can provide to people – both access to the real world and to the growing Information Society world. eAccessibility also implies a need for new technologies and systems themselves to be accessible – especially to users with functional impairments, older people and others who may be in danger of being left behind by the rapid advances of technology in all areas of society.

eAccessibility, in addition, refers to the need of developing specific technologies which will compensate or restore impaired functions, thus facilitating an active participation and integration in society for persons with disabilities." (EDeAN 2003)

One of the objectives of the eEurope action plan is the integration of older people and people with disabilities into the information society. This will only come about as a result of designing mainstream products and services to be accessible by as broad a range of users as possible. In this context, e-Accessibility encourages:

1. Design of information society technology, products, services and applications, which are demonstrably suitable for most of the potential users without any modification.
2. Design of products, which are easily adaptable to different users (i.e. by incorporating adaptable or customisable user interfaces).
3. Design of products which have standardised interfaces, capable of being accessed by specialised user interaction devices (EDeAN 2003).

In accordance with the "design for all" principle, the Personal Navigation (NAVI) programme emphasised equality: new technology should be available and affordable to all citizens (Rainio 2003). Likewise, the Web Accessibility Initiative, which is one of the results of the World Wide Web Consortium (W3C), commits to lead the Web to its full potential including promoting a high degree of usability for people with disabilities (www.w3.org/WAI). In the USA also legislation aims at assuring the accessibility of IT services (e.g. the Telecom Act 1998).

The forthcoming ISO/CD 20282 standard emphasises user characteristics and contexts of use (Schoeffel 2003). The standard recognises the importance of including the growing proportion of older persons, as well as including the needs of disabled people. Better usability is a key factor in enabling elderly people to continue to be independent and to profit from modern technologies.

Actions towards universal usability have started at organisational level (e.g. the above-mentioned EDeaN network) and on a scientific level (e.g. the journal *Universal Access in the Information Society,* and the International Conference on Universal Access in Human–Computer Interaction, both since 2001). Still, what needs to be done is to take concrete actions within individual companies and organisations to adopt the design-for-all principle in such a way that the approach has a real influence on their products.

There are also *further ethical issues* that should be considered in the design and development of technologies. The products and systems are not just neutral tools; they embody certain uses and thereby also certain values. Through the design decisions made by designers and through marketing, certain values are embedded in the products. Ethical principles are always related to a certain time and place. Every society and every interest group forms codes of its own, and some notions that seem ethical at the time may prove to be unethical in the future. Thus, applied ethics cannot be practised without a profound understanding of the prevailing cultural and social context (Topo 2003).

As information technology becomes embedded almost everywhere in our environment, information about us and our behaviour may be collected, integrated and used in different ways. Privacy protection is related to the right to collect or generate personal information, use that information, store the information and forward the information. Current legislation is the basis for privacy protection but social regulation can also create rules and norms for different situations in which location-aware services are used (Ackerman et al. 2001). Espinoza et al. (2001) emphasise the right of the user to remain anonymous. Marmasse and Schmandt (2000) suggest that problems with privacy could be avoided by collecting and analysing the information solely on the user device. Ljungstrand (2001) and Ackerman et al. (2001) point out the trade-off between privacy intrusion and user benefit. They think that, if the benefit is perceived as large enough, some degree of privacy loss will probably be accepted. Continuous requests for permission may overwhelm the users and may disturb the user in his/her activity.

Many experts in the computer ethics world have serious concerns about pervasive computing. The key issues are *privacy and freedom*: what will be known about us and how that information will be used. Technology is not ethics-neutral, and the developers of the technology cannot leave the responsibility of the ethical implications to others. However, it is impossible to ensure that technology is being used solely for the purpose it was designed for. Legislation always tends to be one step behind the technology, so one cannot rely on legislation to take care of things. What is needed is public dialogue in which all actors participate (Stone 2003). Because the choices made in the development phase affect the outcomes, it is vital to incorporate ethical audits as an essential part of the whole design project. The practical ethical audit methodology should be developed in close relation to the human-centred design approach (Topo 2003).

4.3 The new economy

The exploitation of new technology creates a new operational environment, a digital economy. It embraces all branches of the economy, brings forth more co-operation and networking between companies, and increases international activities. In several international comparisons Finland has been rated as one of the leaders in the knowledge society development. The benefits of these technological advances for national economical development are constrained by social factors shaping the implementation of available technologies. Technology is a necessary but insufficient element for a successful network economy business (Oesch et al. 2003).

It has been estimated that the penetration of a new technology into the society takes approximately 30 years. To really reach the market, the new products and services should be affordable to the users and reasonable business to the organisations involved in the service chain. That is why the business models and the pricing models should be developed and assessed parallel to the design process.

To ease the adoption of new services, they have to be integrated into the existing service entities, or the new products have to create new, meaningful service entities. This also requires new business models where each actor brings in one link into the business chain. The business chain has to create meaningful business for each actor in the chain. The products and business models have to be designed for international markets because often the domestic markets do not provide enough business potential.

As the competition gets tougher, each business actor has to focus on their key know-how. This requires chaining with other actors, and finding one’s own position in the chain (Juhola et al. 2003). As product development cycles get faster, the time for utilising possibilities gets shorter. Time-to-market needs to get shorter as well.

Old business models cannot be transferred as such to new technology environments. Media business has had to redesign their business models in the network economy, and many actors have changed their business focus. Peer-to-peer communication will be an important part of the business in the future, and the business models should take into account users as service and content providers (Juhola et al. 2003). Japanese i-Mode, a mobile Internet solution by NTT DoCoMo, is a good example of success achieved by designing the business model parallel to development in the technology and services.

4.4 Network organisations

The emergence of the network economy puts pressure on re-organising business processes, organisational structures and human resource practices (Ruohonen et al. 2002). In current business life, collaboration is not based merely on transferring commercial transactions between companies, but also includes sharing knowledge, uniting and integrating processes, and developing joint measures for operations. The management of knowledge networks grows a critical success factor (Ruohonen et al. 2002). Strong foundations and mechanisms are needed for establishing the most advanced collaborative and network-based industries and organisations. It has been anticipated that in a few years most enterprises will be part of some sustainable collaborative networks that will act as breeding environments for the formation of dynamic virtual organisations in response to fast-changing market conditions. It has also been assumed that a substantial impact on materialising networked collaborative business ecosystems requires a comprehensive holistic approach (Härmä & Nupponen 2002).

Information networks create links between places and shape the structuring of time and place (Golledge & Stimson 1997, Webster 1995). The integration between tele-communication technologies and programming has enabled the development of networks that are qualified by the increase in speed and amount of information streams. This traffic constitutes the most important aspect of the networks. The increase of international connections and the diminishing role of physical distances between places may improve the economical possibilities of peripheral areas in Finland and facilitate their cultural and societal development. In a global world, consumption habits and cultural needs tend to become uniform and controlled by mass production. This development may be considered a threat to the cultural diversity of the world. Globalisation typically changes the prerequisites of primary production and industrial activities, but also induces changes in the service sector and in international transportation activities (MinTC 2000). Networking is considered one of the central features of the information society. It has even been proposed that the term "network society" should be used to denote the information society (Castells 1996).

4.5 Pressure on learning and flexible competencies

Learning is one of the core processes of the knowledge society (Tuomi 2001). It has the function of socialising humans as new competent members of the culture. As learning also constitutes a process through which new knowledge is constructed, it is the major adaptive resource that supports surviving in a changing environment. The traditional concepts and theories of learning have, however, been found to be insufficient in conceiving the constructive aspects of learning (Engeström 1987, Hakkarainen et al.

1999, Kirjonen et al. 1999). Further features of learning that attract attention in the current discussion are its situational, participatory and social nature. Furthermore, the notion of interconnectedness of the emotional and rational aspects of human conduct and learning has currently gained acceptance among researchers, pedagogues and human resource developers. The theories of learning have traditionally focused on learning in children and young people. However, when considering the needs of the information society and the changing demands of working life, adult learning and learning across the life-span have become important issues. (Engeström 1999, Lave & Wenger 1991, Wenger 1998).

On a more global perspective, the central characteristic of the information society is the ability to make *innovations,* i.e. to produce novel and original products and services in order to compete in global markets. When realising this perspective it is important to understand the cognitive, social and cultural prerequisites for innovations, and the co-operative processes of making innovations in research and development teams. It is also necessary to gain insight into the policy and institutional prerequisites that facilitate innovative work (Miettinen et al. 1999, Noteboom 2000, Saari 2003).

Organisational learning is a source of innovation in information society. This issue has gained interest in recent years. The most influential work to date is that by Nonaka and his collaborators (Nonaka & Takeuchi 1995, Nonaka & Teece 2001). Nonaka constructed a model of a cyclic learning process by distinguishing conversions between two forms of representation of knowledge, i.e. the conversion from tacit knowledge to explicit, and from explicit to tacit. Four faces of development emerged: socialisation, externalisation, combination and internalisation. This model may be and has been used as a frame in empirical research that reveals actual innovative processes on the shop floor and within teams (Engeström 1999). The concept of organisational learning focuses, however, on the organisational structures needed for improving competencies in work organisations.

The concept of *work process knowledge* has been introduced to denote actual learning processes on the shop floor and by individual workers (Boreham et al. 2002). This concept draws attention to the necessity of building bridges between situated experiences and tacit skills, and of a more generic theoretical understanding of work and its constraints. A derived concept is *work process learning* (WPL), which underlines the need for improving learning from daily experience. It is evident that the knowledge and skills that are needed in complex and dynamically changing work cannot be acquired in initial formal training, nor only in refresher training. Facilitating shop-floor level learning processes assumes analysis of the core content of the tasks. A methodology called Core-Task Analysis has been proposed for this aim (Norros 2003, Norros & Nuutinen 2002). WPL comprises reflection on the usually tacit practices and core-content of work. It attempts to develop core-task informed practices and operative knowledge. For example, in the paper industry, major improvements in the control of work were achieved through systematic improvement of the conceptual mastery of skilled operators (Leppänen 2001, Seppänen 2003).

One further motivation for improving learning is the ageing of the working population in all European countries. A generational change of personnel is predicted to take place over a short period of time and is expected to be a major problem in production system domains, where expertise has traditionally been developed and maintained in tacit form in implicit knowledge and skills. (Figure 10)

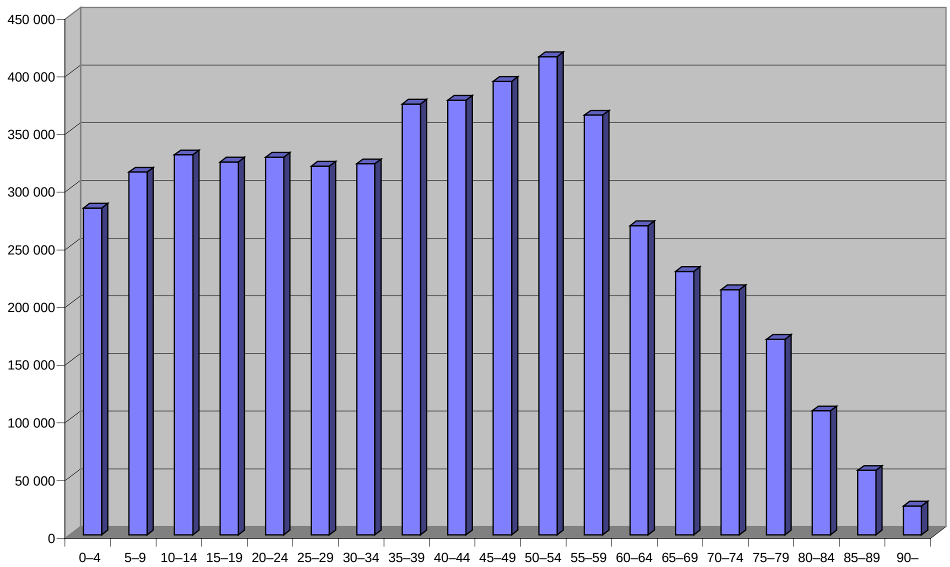

Figure 10. Age division of the population of Finland in 2002 (Statistics Finland).

4.6 Complexity of work and the living environments

One of the most fundamental endeavours of the human being is to maintain control in a continuously changing environment. This control consists of the linkage between perception of the world and acting upon it. Interpretative actions are required to organise the organism towards the environment and produce assumptions about the state of the environment (Norros 2003, Peirce 1998). In a traditional environment humans may act intuitively on the basis of their experience of the relevant cues.

It has been suggested that the disparity between the larger range of what may naturally be perceived and the smaller range of what can be manipulated creates a tension and major motivational force for human exploration (Hancock & Chignell 1995). As science and technology increase manipulative abilities, they simultaneously also extend the range of the observable. This increases the mediatedness of actions, i.e. we must rely on representations of real entities. In the information society, the world is increasingly represented in numbers and text. Mediatedness results in a divorce of actions from direct experience. Comprehension of the state of the world becomes a more demanding task for people because intellectual interpretative abilities are required (Zuboff 1988). Insufficient abilities for interpretation creates a risk of losing control over the environment and one's own behaviour in that environment.

With the increase of information technology the objects of control become larger and more complex. Dynamic features like fast changes provide further difficulties in the control, and time lags may endanger the comprehension of causal relations. The systems are contingent and unexpected phenomena may take place.

Problems in controlling the environment may become manifest in different spheres of human behaviour. Human error, incomplete exploitation of the possibilities of new technologies and distrust of artefacts, and emotional resistance to technological changes are some typical examples. Not only incidents and accidents, but also quality problems, are further evidence of problems in the management of dynamic, complex and uncertain environments.

One expression of being in control of technology is that new artefacts may be used in an *intuitive* or natural way. Intuitive tuning with the environment is a complex phenomenon. It relies on direct perception but assumes experience that makes the environment "natural". The demand for intuitiveness has become an issue via the possibilities that the new interface technologies provide. Interest in ecological psychology (Gibson 1977, Norman 1998) and in ecological design approaches has simultaneously increased (Flach et al. 1995). The ecological approach refers to conceptions in which human action is viewed from the perspective of interaction between the human and the environment. It draws attention to the fact the variability in human behaviour does not only result from variations on the human side, but also from variations in the environment. The latter source of variability has been neglected in the prevailing information processing psychology.

The issue in ecological design is to make the invisible world visible. This sets the requirement for design to make use of theoretical conceptualisations of the object and new visual ways of representing the object (Vicente 2002). The possibilities and constraints of the environment are affordances that human beings may utilise (Gibson 1977). People must, however, be equipped with adequate perceptual and intellectual habits in order to grasp these possibilities (Norros 2003).

4.7 Impacts of culture on the development of technology and organisations

The *division of time* between *home and work* is one important issue of the future mode of living in an information society. In the traditional situation, the relationship between work and private life was based on segmentation that made a sharp distinction between the two spheres. Today the relationship tends to become blurred (Castells 1996). However, responsibility to control the workload and stress is mainly on the person him/herself (Ruohonen et al. 2002).

New information and communication technology has also enabled an increase of remote work, which is a further aspect of blurring of work and private life. In 1997 about 12.5% of wage earners in Finland were officially registered as accomplishing remote work at home. The rate of increase of the proportion of people working remotely has, however, slowed down recently (Pekkola 2002). It appears that new work orientations and cultures are currently emerging that convey changes in the system of values and in the significance that work has in people's entire life. Critical observers have expressed concerns about the effects of the new work culture on the control of life, family and wellbeing of people (Härmä et al. 2002, Nätti & Anttila 2002). The evident problems of finding new sustainable forms of mastering the complexity and uncertainty of modern life give rise to many new interdisciplinary research tasks.

In this report we distinguish between the notions of "usage culture" and "organisational culture". The former refers to attitudes, assumptions or dispositions that people have concerning the everyday built environment and the appliances they use in their normal daily activities. With consumer products, the trend is that people are not ready to put much effort into learning how to use new systems. Future users would like to take new products as adaptive tools that they can shape to their own usage needs. Shneiderman (2003) points out that information technology should support human needs for mobility, ubiquity, creativity and community. He points out that it is time to transfer the focus from what computers can do to what people can do.

One of the features of the present usage culture is the emergence of new types of high-technology games. Not only children but many young adults are interested in this new leisure-time activity. High economical expectations have been invested in this domain. Games will also mix with other forms of entertainment and education and in these cases new interaction technologies can be used (Strömberg et al. 2002, Leikas et al. 2001).

Network organisations and other modern forms of organising work are linked to the development of adequate cultures and practices among the personnel of these organisations. There are numerous large-scale breakdowns or accidents in industrial plants, transportation systems or societal infrastructures that provide evidence of the role of the organisational culture and everyday practices of personnel and management on the safety and efficiency of these systems (Gauthereau 2003). Organisational culture has been defined to consist of the shared assumptions about the organisation’s basic mission and the means to achieve it. Culture is partly unconscious and the assumptions are not easily called into question. By incorporating what is considered to be acceptable and desirable in a community, culture functions in a generic and thorough-going regulatory role, which may be identified in the conceptions, actual decisions and actions of the actors. It is necessary to understand what organisational culture as a phenomenon is, how culture is actually constructed, and what are its specific forms in today’s working life. When developing working practices and redesigning organisational structures, assessing the impact of an organisation’s culture becomes crucial (Reiman & Oedewald 2002b, Schein 1999, Schulman 1993).

Typically, organisational culture has been studied with concepts and tools that refer to very generic human values, basic assumptions, or also typical everyday practices in which these manifest themselves (Cameron & Quinn 1999). Management of risk and quality in particular organisations requires understanding of how the critical intrinsic demands of the work domain are reflected in the shared attitudes and values of the personnel. Culture must, therefore, be understood and analysed in contextual terms. The starting point is that culture expresses what the actors of the particular community consider significant and meaningful in maintaining the functions and pursuing the goals of the organisation. The dispositions of personnel towards professional tools and information systems are included in the conception of organisational culture (Reiman & Oedewald 2002a, Reiman & Oedewald 2003).

5. Technical drivers

5.1 Recent information technology roadmaps

Several information technology roadmaps identify trends in user interface technologies or identify technologies that may affect HTI in the future. In this chapter we refer to the following roadmaps:

- ITEA (Information Technology for European Advancement) is an eight-year strategic pan-European programme for advanced pre-competitive research and development in embedded and distributed software and resorts under EUREKA. It has created a RoadMap for Software Intensive Systems in 2001 (ITEA 2001). The Roadmap deals with the time span 1999–2007.
- The IST (Information Society Technologies) Advisory Group (ISTAG) produced a set of scenarios for Ambient Intelligence in 2001 (ISTAG 2001). The scenarios describe how Ambient Intelligence (AmI) might affect the life of ordinary people in 2010. The aim of the scenario work was to help identify key technologies and focus the research efforts of the EU.
- The work programme of the sixth Framework Research and Development Programme "Information Society Technologies" by the European Commission (2002–2006) can also be seen as a kind of technology roadmap (EC 2002).
- VTT has published roadmaps of four different research topics related to communication technologies relevant for VTT in 2002 (Sipilä 2002). The four topics include: Interoperability and Mobility in Future Networks, Micromechanical Radio Frequency Systems, Service Architectures and Smart Human Environments. This last research topic is most relevant for HTI.
- Media Technology Outlook (Juhola et al. 2003) by VTT Information Technology aims at identifying the core technologies likely to have a major impact on the media industry up to 2010.
- Oesch et al. (Oesch et al. 2003) have published an overview of the technology and business trends related to IT services in the future network-based economy. The overview formed the basis for TEKES Research Programme "Interactive Information technology" (2003–2007). The overview is based on interviews with different actors in industry, academia and research institutes.
- VTT has published a survey of research topics related to UbiCom (ubiquitous computing and ubiquitous communication) (Ailisto et al. 2003b).
- The Intelligent Automation Systems technology research programme by TEKES has resulted in a draft technology roadmap (Ventä 2003), which describes current and

future challenges for intelligent automation and related software engineering practices. The focus of the roadmap is on process and production control and automation systems.

- HUMANIC is an ongoing roadmap project coordinated by Teknologiateollisuus ry. The project focuses on user interfaces in the cabins of future work machines and vehicles (www.teknologiateollisuus.fi/index.php?m=5&s=3&id=2947).

Accordind to ITEA *Human System Interaction (HSI)* will need to (further) become uniform and flexible, self-explanatory and simple, context-dependent and self-learning (ITEA 2001). HSI will be proactive, reliable and forgiving. Means for validation and measurement of satisfaction are needed to guarantee proper and desired functionality. Multimodal user interfaces will utilise natural language, voice, gestures and eye gaze. ITEA presents the categories of user interface technologies as a roadmap from 1999 to 2007 (Table 2).

Table 2. ITEA roadmap for user interface technologies.

Human System Interaction[1)]	Now	Short term	Medium term	Long term
Multi-modal user interface				
– voice command	•	•	•	
– speech to text		•	•	•
– natural language speech recognition			•	•
– text to speech	•	•	•	•
– gestures		•	•	•
– eye movement			•	•
Multi-user interfaces				
– 2-D presentation		•	•	•
– 3-D symbolic presentation		•	•	•
– 3-D real presentation			•	•
Adaptable user interface				
– user profile		•	•	•
– learning user interfaces			•	•

[1)] The dot in the table that relates to the time line indicates the start of deployment of the technologies. When more than one dot is shown, this indicates different generations of the technology.

Most of the roadmaps recognize *ambient intelligence* (also referred to as ubiquitous computing, smart human environments) as one of the main trends in information technology. ISTAG scenarios stress that people are in the centre, and that Ambient Intelligence (AmI) technology should help them in everyday situations (ISTAG 2001). The following critical socio-political factors were identified based on the scenarios:

- AmI should facilitate human contact
- AmI should be orientated towards community and cultural enhancement
- AmI should help to build knowledge and skills for work, better quality of work, citizenship and consumer choice
- AmI should inspire trust and confidence
- AmI should be consistent with longterm sustainability – personal societal and environmental – and with life-long learning
- AmI should be controllable by ordinary people.

The scenarios also gave rise to some thoughts on the complex business models that will need to be developed in order to produce and maintain the necessary technologies and services. Partnerships and complex combinations of different business models were anticipated (ISTAG 2001).

According to ISTAG, key technology requirements for AmI include very unobtrusive hardware, seamless mobile/fixed communications structures, dynamic and massively distributed device networks, natural-feeling human interfaces, as well as security and reliability.

Ailisto et al. suggest that research related to UbiCom should be interdisciplinary, involving human sciences, usability studies, business and economic research, as well as legislation and ethical issues (Ailisto et al. 2003b). Application and technology viewpoints must be combined. Core technology research should address short-range wireless communication, middleware, reasoning and smart algorithms, as well as sensors and actuator technologies.

The expected breakthrough of UbiCom has not arrived yet. Some of the reasons are mentioned by Ailisto et al. (Ailisto et al. 2003b), and include technical complexity, cost factors, ethical and socio-political obstacles, irrelevancy of initial demonstrators, and complex business models.

Ailisto et al. point out important HTI research areas: reasoning methods (context awareness, pattern recognition, personalisation, profiling and smart algorithms) and usability research (adaptive UIs, UI technologies, design for all, context sensitive UIs including location sensitivity, and multimodality) (Ailisto et al. 2003b).

Figure 11 gives an overview of the most important identified trends in VTT's Roadmap for Smart Human Environments (SHE) (Plomp et al. 2002a). Smart environments will include several devices that communicate together and that the user can communicate with. These systems will be context-aware – they will identify the current context of use and adapt their behaviour accordingly. The path towards calm computing where information technology is ambient but invisible goes through developments in *context-awareness, personalisation* and *user interface technologies*. Smart products and environments raise new challenges not only for the technology itself, but also for the human-centred design methods with which the systems are being designed.

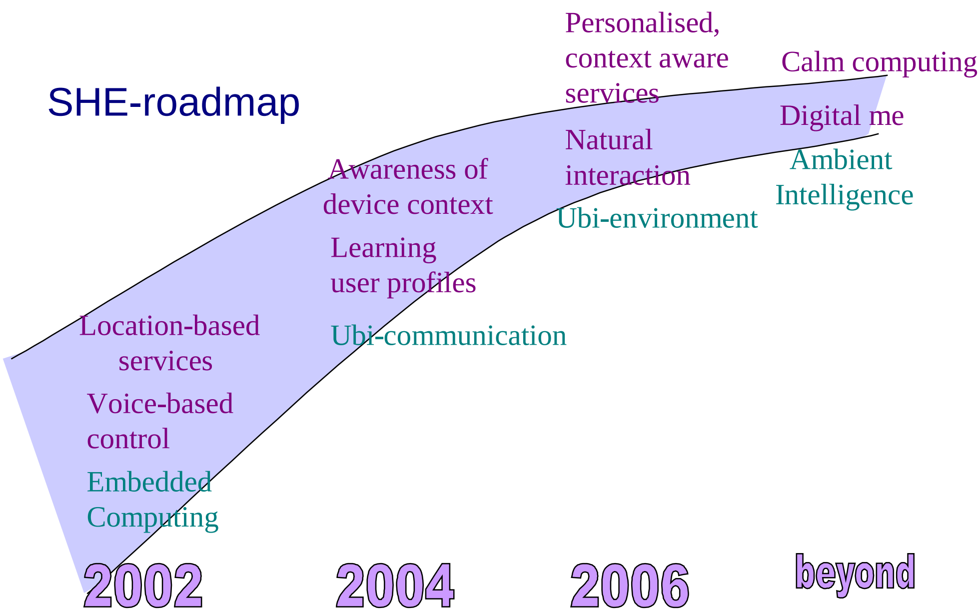

Figure 11. Excerpt from the Roadmap for Smart Human Environments (Plomp et al. 2002a).

The sixth Framework Research and Development Programme "Information Society Technologies" by the European Commission (2002–2006) also emphasises ambient intelligence where computers and networks will be integrated into the everyday environment, making a multitude of services and applications accessible through easy-to-use human interfaces (EC 2002). The IST vision places the user, the individual, at the centre of future developments for an inclusive knowledge-based society for all.

IST today	*The IST in FP6 vision*
PC based ………………………………	"Our surrounding" is the interface
"Writing and reading"……………… …	Use all senses, intuitive
"Word" based information search………	Context-based knowledge handling
Low bandwidth, separate networks…. ….	Infinite bandwidth, convergence, ..
Mobile telephony (voice)………….. ……	Mobile/Wireless full multimedia
Micro scale………………………………	Nano-scale
Silicon based……………………………..	+ new materials
e-Services just emerging………………..	Wide adoption (*e*Health, Learning,..)
< 10% of world population on-line….. …	World-wide adoption

Figure 12.. Technology vision by EC's IST research and development programme.

In the media business *new distribution channels, information carriers and terminals* will offer end users a variety of new alternatives like digital books and digital television and its services. The main trends in ICT will be increasing speed, storage and battery life as well as decreasing size and price of ICT services. The utilisation of ICT in the media business has led and will lead to structural changes across the traditional boarders of branch and market segments. Media convergence and globalisation of the ICT industry will lead to new business models. Customer to Customer (C2C) business will have growing importance. From a usability point of view, key issues in the future will be understanding the customer's rational and emotional needs, media choice and user experience of different media (Juhola et al. 2003) (Table 3).

Table 3. Roadmaps of technologies vital to multiple media development (Juhola et al. 2003).

Technology	2002	2004	2006	2010+
Personalised, context-sensitive multiple media	Electronic identification Web-services using customer profiles Location based services Sensor based reactivity	Profile-driven services with learning features Wearable embedded sensors Awareness of device context	Trusted biometric identification Personalised context-driven services Personal navigation guides (enhanced reality) Portable private profiles	Digital me Awareness of social context
Broadcast systems	Digital TV Mobile TV in pilot phase Digital movies start	MHP breakthrough Interactive services using the return channel IP television emerging commercially	Analogical radio spectrum released for digital use VOD in broadband networks (TVAnytime) Mobile TV (TVAnywhere) Integrated services (4 G: DVB + UMTS + WLAN) etc Digital movies established	3D-television in pilot phase HDTV in pilot phase IP-television established
Community media and media production	XML based systems available, but in isolated environments Knowledge management in use in large corporations Mobile games	Sophisticated knowledge management tools available for companies Semantic web and web services emerging in commercial applications Multi-user game communities	Integrated XML based applications VR-games	Semantic web based integrated applications in use Semantic web in full use in knowledge management Immerse environments (3Dcaves, augmented reality)
Enabling technologies – image, audio, video processing – system integration – programming languages & methods	Speech recognition In limited use	Databases based on XML, RDF, ontologies	Distributed databases Video compression: VHS video quality at 100 kbit/s	Speech recognition integrated in user interfaces Efficient develop-ment environments Component libraries

Oesch et al. (2003) point out that the Internet is becoming a global distribution channel. The growing economical importance of the Internet requires usable and reliable paying methods as well as feasible business models. Semantic Web will combine meaning and structure, thus integrating the Web into a huge relation database. Network services will integrate together into meaningful service entities, thus providing increasingly useful services to users. New wireless services will be introduced but consumer acceptance for them is difficult to predict.

Ventä introduces HTI challenges in industrial automation and process control systems (Ventä 2003). The systems are manifold and complex. Some concepts and architectures date back to the time before digitalisation. The old functionalities remain in the systems while modern technologies are simultaneously adopted. Both systems and personnel have to deal with hybrid life cycle phases. There are significant gaps between process design, product design, and automation design. Increased intelligence of systems tends to lead to an increase of complexity in the human-system interface. The interface between the control system and the service system is often missing.

HUMANIC project www.teknologiateollisuus.fi/index.php?m=5&s=3&id=2947) (Naumanen 2002) has recognised trends in HTI in vehicle environments. The functions available to the driver are moving far beyond direct driving and working functions. This is enforced by the increasing number of communication and information systems, and of comfort and driver assistance systems. Key technology trends in this application area address intelligent filtering of information provided to the driver, multimodal user interfaces, driver identification, personalisation, detection of the driver's status and behaviour, expanding the driver's perception (e.g. night vision) and different safety systems (especially pre-crash systems). Key user interface technologies include touch-screens with haptic feedback, voice recognition, text-to-speech systems, and head-up displays. The status of the driver can be monitored by measuring eyelid movements, eye position, blinking, gaze direction, steering grip pressure and head pose.

5.2 Wireless future

Aaron Marcus and Eugene Chen describe their research of a wireless future, aiming for the design of useful and usable mobile devices that could overcome extreme input and output challenges and become true personal companions (Marcus & Chen 2002). They identified five usage spaces: information, self-enhancement (extending one's normal capabilities), relationships (enhancements to communication, e.g. presence), entertainment and M-commerce.

Marcus and Chen point out two alternative trends in the development of mobile devices: the device can either be an information appliance specially designed for a certain user task or a "Swiss army knife" type, useful in many different situations. Both solutions have their benefits and drawbacks. Integrating many different functions into a single device may make the user interface complicated and the device non-intuitive (Norman 1998). On the other hand, it might be impractical to have several different information appliances for different purposes.

According to Marcus and Chen, a mobile device can represent the metaphor of a wallet, a purse, a backpack or a briefcase, containing different information and tools respectively. Context awareness, especially location awareness, can solve problems related to baby-face displays and tedious text input by giving the user easy access to the services relevant in his/her current context. Time-shifting: "start now, finish later" will be important in mobile services that are often used during casual empty moments. Also context-based reminders like "reply to this at home" will be useful.

Donald A. Norman believes in information appliances, a wide range of computer-based devices that are designed to fit the tasks that people want to do. In the future, computers will be integrated into different things so naturally that people do not think about "using a computer" (Bergman & Norman 2000). Norman refers to motors that are currently integrated into household equipment. People do not think about using "motors" when running the washing machine, mixer or coffee grinder. Norman believes that the same will happen with computers. Future IT products will be designed for everyday people, not for early adopters or technologists. The products are meant to fit one's lifestyle and give value and convenience. This requires a different approach to design: you have to observe the way people live their lives before you can design the product to fit naturally and seamlessly into their lives.

5.3 Growing variety of devices and infrastructures

Olsen pointed out the challenges that the transition from one computer per person to one computer per task will bring along (Olsen 1999). The transition will lead to more kinds of computers, more kinds of information, more ways to communicate and more ways for organising all the above. However, users need to communicate with people and information related to their tasks, not just those with compatible devices and software. Olsen wondered whether it would be possible to port every new solution to all possible computing devices, or whether some devices had to be sacrificed. He suggested that human consumable data types are those that will be less likely to change. That is why tools should be built around those data types, and the tools should facilitate information integration, collaborative communication and situation-adapted computing devices. To master the chaos, technologies should be developed in the user domain rather than data domain.

Olsen's vision has become true especially with the World Wide Web. The Web is becoming accessible from a wide range of devices including traditional computers, mobile phones, PDAs, digital televisions and other devices with varying user interface capabilities. Also the network connections vary, settings limits to the amount of information that can be transferred. The variety of devices is so high that it is very difficult to design a new service such that it would work optimally on all those different platforms. In practice, service providers have to decide which devices they can and have to support.

The World Wide Web Consortium (W3C) has identified the threat and has established Device Independence Activity, the aim of which is to ensure that the Web universe will not get fragmented. The W3C Device Independence Activity is working to ensure seamless Web access with all kinds of devices, and worldwide standards. The Working Draft of Device Independence Principles (2001) is a guide for other W3C working groups and organisations external to W3C who develop Web content authoring and delivery technologies. It sets forth a foundation for building device-independent guidelines, mark-up languages, and tools. It aligns the work of this Working Group with W3C's Web Accessibility Initiative and Internationalisation Activity because these Activities can work together toward the common goal of Web access for "anyone, anywhere, anytime, anyhow" (W3C 2003).

5.4 Increasing availability of information

Human working memory can only hold five to nine chunks of information at a time. Today's systems can overwhelm users with data, leading to information overload. The challenge to human-computer interaction design is to use advances in technology to preserve human attention and to avoid information saturation (Siewiorek 2002).

Basically, users will benefit the more information they have access to. The problem is how to find the right information and how to make sure that the information is reliable. As Web information contents have grown, so usage patterns have changed from browsing to searching. Efficient search engines are vital for using the Web. In the future, the semantic Web will include more and more metadata, information that describes the characteristics of the actual information. Semantic Web requires new types of search engines to help users find the information they need from the global information storage, the Web.

With modest Internet devices like the mobile phone or digital television, service providers often think they could prevent information overflow by restricting the information contents of the individual service. However, users will need access to all relevant information, as deep as they are prepared to go, but the information will have to be structured in such a way that the user can choose to get the information in small portions.

Discovery services is a new paradigm for service provision to mobile users. The idea is that mobile users and terminals can retrieve and interact with services that are available in their network locality. Thus services are more easily available where they are most relevant. Proactive systems may even provide information and services automatically to users.

Users will need efficient tools to control what information they want to receive, from where and when. In Europe and the US there is strict legislation against pushing information onto users. Basically, information pushing is not allowed without the permission of the user. Nonetheless it still happens, e.g. in the form of junk email. In Japan, the legislation is more permissive. This has quickly led to a situation where users get huge amounts of junk mail in their mobile email accounts. Users have to continually change their email addresses to keep the amount of junk mail under control.

Context-awareness and personalisation are often good solutions for coping with information overflow. These issues are dealt with in Chapters 5.7 and 5.8.

5.5 Improved possibilities for information management

Information and the ability of people to convert it into useful knowledge are core capabilities for integrating human and technical resources. Information technologies that provide multiple views of information, alternative interpretations, and guidelines for selecting among those views will be needed.

Knowledge management refers to a cluster of software technologies spanning software programming, data processing and artificial intelligence. Data capture, data mining and warehousing technologies are critical technologies at the moment, and are beginning to achieve widespread use. However, as the scale of use expands, e.g. with the global growth of e-commerce and requirements for distributed networks, new techniques for identifying patterns in data are required. The fact that the biggest investors in raw computer power in the world today are the security services (CIA) and the credit/debit card companies (e.g. Amex) indicates that managing global databases is likely to be one of the major areas of demand for the growing computer power. The global data system is expected to fuel demand for supercomputing and for software tools to sort and manage this information.

Standards for the exchange of information between people, between organisations, between people and machines, and between machines is fundamental to the integration of human and technical resources. Protocols for communications will provide significantly more capability, but also greater flexibility to allow for intelligent human-machine interactions. Making distributed databases inter-operate is a key driver of development efforts in software agents.

Voice, language and pattern recognition systems will evolve rapidly. Voice synthesis systems are already well developed, but it is expected that by 2006 they will be indistinguishable from human voices. Translation of natural languages is an area of challenge particularly for European countries. Breakthroughs are expected here through to around 2010 so that portable translation devices ('Babel Fish') and instant text translation will be available for all on-line material. Pattern recognition is more difficult, because the meanings of patterns are often not related to easily recognised variations in their surfaces, distributions or topologies.

5.6 Ambient intelligence

Ambient intelligence (AmI) is perhaps best described by means of its three most important enabling technologies: ubiquitous computing, ubiquitous communication and intelligent intuitive interfaces.

Lyytinen and Yoo point out that *ubiquitous computing* will integrate the advances in both mobile and pervasive computing (Lyytinen & Yoo 2002). They define mobile computing as the capability to physically move computing services with us, thus expanding our capabilities to inscribe, remember, communicate and reason independently of the device's location. The other dimension, pervasive computing, implies that the computer has the capability to obtain information from the environment in which it is embedded and utilise it to dynamically build models of computing. This requires that the environment also is intelligent, i.e. able to detect and communicate with computers entering it. The main challenges in ubiquitous computing originate from integrating large-scale mobility with pervasive computing functionality (Figure 13). In its ultimate form, ubiquitous computing means that any computing device that we carry with us can anywhere dynamically build models of its environment and configure its services accordingly.

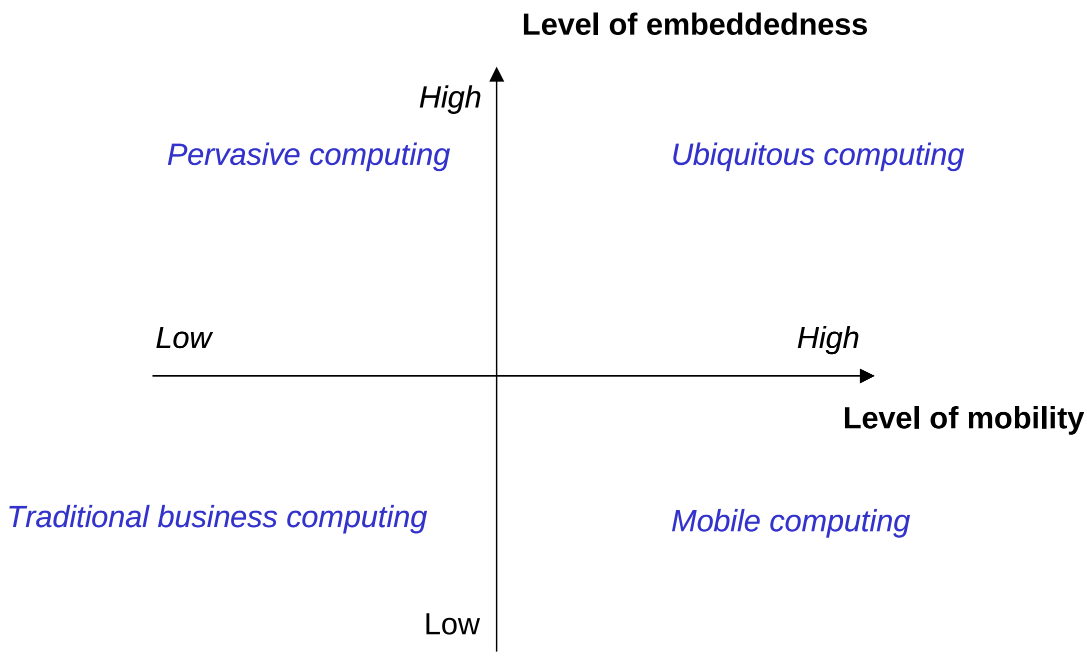

Figure 13. Ubiquitous computing includes both technology embeddedness and user mobility (Lyytinen & Yoo 2002).

Ubiquitous communication means enabling anytime, anywhere communication of anything with anything else, not only people but also artefacts. Central technologies in ubiquitous communication are ad-hoc networking and wireless communication technologies.

AmI stresses natural human behaviour and thus evokes demands for new user interfaces. It includes smart environments with hidden or shared user interfaces, as well as personalised user interfaces, such as future clothes, that are adaptive and proactive according to the user's needs. People will interact with the environment and with each other using multiple modalities, e.g. their body movements, voice, gestures and touch instead of using conventional computer controls. Novel user interfaces are described in Chapter 5.10.

An AmI infrastructure provides a seamless environment of computing, advanced networking and specific interfaces. The infrastructure is aware of its users and usage context, and is capable of responding to user needs intelligently, or remain unobtrusive, even invisible, when it cannot. The AmI is the intelligence of this infrastructure embedded within the actual applications. These applications integrate the required enabling technologies to perform certain advanced functions, which may be either pre-programmed or learned by the experience gathered by the system during its existence.

5.7 Context awareness

Context awareness has been defined by the major players in research in slightly different ways, but a crisp definition is missing. Shilit, building as one of the pioneers of context awareness on the work done at Xerox PARC, mentions three important aspects: where you are, who you are with, and what resources are nearby (Schilit et al. 1994). (Dey et al. 2001) complete the definition by defining context as any information that can be used to characterise the situation of entities (i.e. a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Similar definitions were earlier given by Pascoe, Salber and Brown et al. (Pascoe 1998)), (Salber et al. 1999) and (Brown et al. 1997). Dey and Abowd thus define relevant entities as places, people and things, and introduce four categories or characteristics of context information: identity, location, status (or activity) and time. At GeorgiaTech, Salber, Dey and Abowd developed the context toolkit, which aids the development of context-enabled applications by means of context widgets that create an abstraction layer on top of the context-sensing hardware and low-level algorithms (Dey et al. 2001, Salber et al. 1999). An alternative approach was proposed by Coutaz and Rey, who presented a theory of "contextors" (Coutaz & Rey 2002)).

Context consists of the physical context, the social context and the intentional context. Additionally, the user can be seen as part of the context as well, when reasoning from the point of view of the device. The user as context and the applications adapting to the user are often dealt with separately under the user identification and personalisation terms. The main problem with context awareness is that contexts are often difficult or even impossible to measure. Sometimes it may be beneficial to let the user define his/her own contexts if this does not require too much effort from the user.

Physical context

The physical context consists of the devices around the user, the environment itself and possible other artefacts in the environment. One of the most important pieces of context information is the location of the user with respect to this environment. Currently, the user location can be measured with different techniques like GPS, cell-based positioning and proximity based systems (WLAN, Bluetooth). The future trend will be that positioning technologies become more precise and the devices support different positioning techniques, thus providing smooth transitions e.g. from outdoor positioning to indoor positioning.

The physical context also includes the characteristics of user devices and other equipment. Technologies like CC/PP have been developed to provide a framework for communicating the capabilities of the terminal to the service. The devices in the vicinity of the user can be discovered either by combining the positioning information of the user, or by scanning the environment for short-range IR- or RF-based communication channels.

The physical context can also relate to the state of the environment, e.g. the temperature or lighting conditions. Determining the actual environment (e.g. indoors or outdoors, travelling in a car or sitting in a conference room) based on these measurements often requires a combination of cues provided by several separate sensors. Solutions have been proposed, but they often either apply to a very limited set of environments or provide a somewhat unreliable guess of the actual environment.

Social context

The social context relates to the people near the user, or the social situation that the user is in. Establishing the identity of the surrounding people is generally done by means of wireless connections to their mobile terminals or RFIDs worn by the people, since establishing people’s id by other means (face recognition, footsteps, weight, etc) is still rather unreliable. Also establishing the second aspect of the social context – the social situation – is rather difficult to achieve by observation. It is easier to use tags or calendar information to e.g. infer that the user is in a meeting or visiting friends.

Intentional context

This context is related to the task that the user needs to perform. Being at work or spending time at home probably greatly affects the topics that a person is interested in. Knowledge of the tasks and goals of a person also allows for proactive services that actively undertake actions to support the user in his/her task.

Knowledge of the task at hand and the status of the environment is also very important in industrial environments. There e.g. the process status may affect the information that an operator is interested in.

Adaptation

Context information by itself is of limited use. It only becomes valuable when used to adapt the provided services or interaction to the context. Thus personalised, more to the point and easier to use services can be achieved. Adaptation may involve:

- Adapting the interaction – changing the look and feel of the user interface, changing the interface to better fit the terminal features, utilising modalities best suited and supported by the technology at hand, taking the user’s experience in using a certain application into account, etc.

- Adapting the service – providing personalised services by pre-filling forms, tailoring offers, recommending products, giving easy access to services relevant to the user's location, task, etc.
- Adapting the content – providing information relevant to the user's context, task, and interests
- Adapting the environment – changing the environment to better suit the user's wishes (music, lighting), adapting ventilation to the number of people, adjusting car seats to the driver, etc.

5.8 Personalisation

By personalisation we mean the ability of a service (in a broad sense) to be altered to better suit the needs and preferences of individual users. The changes may affect e.g. the means of interaction, the look-and-feel, the content, or the selection of services. As pointed out by Riecken, this is quite a restricted view and the term personalisation can be applied much more widely (Riecken 2000).

The way personalisation is achieved differs between the application areas. The following levels of automation can be discerned:

- Manual personalisation – Tools are provided to the user to adjust the services to fit the user's preferences. One example is Yahoo, where the user can customise the information and its layout shown on the My Yahoo page (Manber et al. 2000). This kind of personalisation derives from macro-building techniques for facilitating often-repeating tasks.
- Profile-directed personalisation – A user is either categorised into a group with an associated profile, or (s)he interactively defines a profile. This profile is then used to filter or structure information to meet the user's interests. The profile definition phase is still manual, but the application requires decisions based on the rules in the profile.
- Learning personalisation – The system observes the user and is able to learn from his/her and other behaviour. The knowledge obtained from these observations is then used to support the user in his/her tasks. This assistance can take the form of recommendation of content, but also of performing actions on behalf of the user. In the case of learning personalisation, the learnt user's profile does not necessarily need to be explicit and can be represented by e.g. a neural net.

The last of these is clearly the most demanding approach, but since the area of application for personalisation is very wide, there are challenges on each level. There will be new challenges for personalisation when applied to shared devices as in a ubiquitous computing applications (Trevor et al. 2002). Combining personalisation with context awareness so that user' s personal preferences for different contexts are taken into account, also constitutes a major design challenge.

5.9 User identification

As organisations search for more secure authentication methods for user access, e-commerce, and other security applications, biometrics is gaining increasing attention. Biometric technology is now being deployed as a means of tightening security and simplifying user access. The prices of biometric products and systems are falling as the demand for this technology grows and more vendors enter the market. Total biometric revenues are expected to grow rapidly through 2005. Much of the growth will be attributable to PC/Network access and e-Commerce, although large-scale public sector deployments will continue to be an essential part of the industry.

Large scale application of biometrics has yet to be seen, and early pilots in the US have not fulfilled expectations, due to lower than expected performance, process models and ease-of-use problems as well as ethical or legislation difficulties.

Development of legislation in the US has stressed the importance of biometrics research by e.g. requiring that travel documents include storage of biometric identifiers by autumn 2004. There has been discussion within the European Union about the introduction of biometric identifiers, for example, in the visa information system and visa stickers.

Technical standardization is driven strongly by the US. The INCITS M1 committee seeks to accelerate deployment of standard-based solutions and ultimately hopes to create formal international standards. The application program interface standard BioAPI has already been accepted by the M1 committee. At international level, ISO JTC1/SC17 has founded the WG11 group for biometric standardization. A co-ordinated European research initiative would help foster European interests in the standardization work.

Biometrics is based on identifying persons by their physical or behavioural characteristics. Several techniques using physical properties exist: fingerprinting, iris patterning, retinal scanning, hand geometry, hand vein, ear, face, face thermograms, odour and DNA. Behavioural techniques include voice print, signature, gait (walk) and keystrokes. The biometric techniques are compared in Table 4.

Table 4. Comparison of Biometric techniques.

Method	Generality	Uniquenes	Stability	Ease of use	Performance	Acceptability	Circumvention
Face	***	*	**	***	*	***	*
Fingerprint	**	***	***	**	***	**	***
Hand geometry	**	**	**	***	**	**	**
Keystroke	*	*	*	**	*	**	**
Hand vein	**	**	**	**	**	**	***
Iris	***	***	***	**	***	*	***
Retinal	***	***	**	*	***	*	***
Signature	*	*	*	***	*	***	*
Voice	**	*	*	**	*	***	*
Face thermograph	***	***	*	***	**	***	***
Odour	***	***	***	*	*	**	*
DNA	***	***	***	*	***	*	*
Gait	**	*	*	***	*	***	**
Ear	**	**	***	**	**	***	**

[Anil K. Jain, Introduction to Biometrics, Biometrics Personal Identification in Networked Society, Kluwer Academic Publishers, 1999.]

By far the most mature method is fingerprinting followed by iris scanning. Within both of these methods, commercial products exist and fingerprint-based systems are finding market acceptance due to their reliability and relatively low cost. Face recognition is being studied by a number of research teams and commercial applications are expected.

5.10 Novel user interfaces

It is expected that already this decade speech recognition, position sensing, and eye tracking will become common user interface input techniques. Towards 2015, stereographic audio and visual output will be coupled with 3D virtual reality information. In addition, heads-up projection displays should allow superposition of information onto the user's environment (Siewiorek 2002).

New, post-desktop, user interface metaphors will be needed especially for mobile use. There may be needs for sets of metaphors, each tailored to a specific application or a specific information type. While several input/output modalities have been the subject of research for decades, the accuracy and ease of use are not yet acceptable. Inaccuracies frustrate the users and the modalities often require extensive computing resources, not available in mobile devices (Siewiorek 2002).

Natural Interaction

Natural interaction refers to a comfortable, intuitive and non-obtrusive way to use technology, often mimicking inter-human interactions. Truly natural interaction will allow people to use technology without prior training. Intuitiveness is a good design goal but it is a culturally determined and learned feature of interaction. Even intuitive user interfaces may require a learning, often also a teaching process from the user.

Natural interaction is only possible when the technology is made smarter, or more aware of its user. The service should recognise its user, know his/her background and understand how the context affects the user's expectations of the service. Furthermore, the interaction should preferably use the most natural modalities and interaction channels (devices, terminals) available for the interaction. Novel user interfaces that utilise different user senses may give rise to safety challenges as well.

Post-WIMP interfaces

Current interaction with (desktop) computers is implemented by means of an interface paradigm generally referred to as *WIMP* (Windows, Icons, Menus, Pointing device). This paradigm finds its roots in the windowing and direct interaction system developed at Xerox PARC and used commercially first in the Apple Macintosh (from 1984), soon to be followed by similar implementations by Microsoft (Windows) and by MIT for Unix (X-windows) (Dettmer 1990)). The current implementations have a remarkable degree of commonality, which has allowed for easy use of different computer systems once the basic principles of WIMP have been mastered.

When small PDA-like devices appeared on the market, they derived largely from the successful WIMP paradigm. But the small display, less precise pointing on the touch-screen and absence of a keyboard called for different solutions. Also large screens have similar problems – although the size invites direct interaction, current pointing technologies have their limitations.

In *ubiquitous computing* the large variety of computerised devices, many of them portable or embedded and wirelessly connected, will make the established desktop paradigms invalid. Also recognition-based user interfaces will set new requirements as well as the increased use of 3D. Work done in the 1980s and early 1990s on user interface management systems and model-based generation of user interfaces may receive renewed attention (Myers et al. 2000).

WIMP interfaces utilise only part of the modalities available in human interaction. Particularly speech, listening, gesturing and gaze are extensively used in human-human interaction and are serious candidates for enhancing future human-technology interaction. Examples of experimental multimodal interfaces can be found from virtual and augmented reality research, one of the oldest being the put-that-there system developed by Bolt (Bolt 1980).

Multimodality

Using many senses and modes of communication is an essential part of the natural behaviour of human beings. Humans have good abilities to receive and process information from many sources simultaneously. Multimodal interfaces use many modalities at the same time, so they take advantage of human interaction and perception abilities. Multimodality allows a transition from traditional windows-icons-pointers-menus interfaces to more natural ones.

In task-oriented applications, like personal navigation, communication or office automation, the purpose of multimodal interaction is to enhance the efficiency and expressive power of the interface. In entertainment or virtual reality applications new modalities can enhance the sense of presence and thus create more interesting experiences (Lainio et al. 2001).

Requirements for effective systems using multimodal interaction are: understanding 1) intended modalities and the information they convey, 2) how to combine the modalities so that they complement each other, and 3) an architecture that can handle time-critical and interdependent inputs and cope with errors in recognising them (Oviatt 1999).

Voice-based interaction

The development of Artificial Speech Recognition (ASR) technology for designing user interfaces has made significant progress over the last decade (Karat & Gardiner-Bonneau 1999, Rhyne & Wolf 1993, Roe & Wilpon 1994). Speech-based systems have mainly been used in the past for command and control of GUIs (Strong 1993) and as a substitute of mouse and keyboards in dictation applications (Danis et al. 1944). In most previous developments, the use of speech interaction was focused on enhancing traditional GUI-based applications by adding speech input facilities.

New HCI trends for UI design propose the use of speech interaction as a *must* for better interface navigation (Cole et al. 1995, Stasko 1996). The improvement of interfaces with speech technology renders traditional HCI into a simpler and more natural way of interacting with computers. The advantages of such interaction modality encompass simplifying the communication between humans and (handheld) computing devices to other non-traceable benefits like reducing tendonitis caused by wrist strain (associated with long periods of mouse operation).

There are ample social situations where voice interaction would be disturbing, and in many cases the traditional WIMP paradigm, if available, outperforms voice interaction. However, in many situations voice interaction can help the nomadic, occupied or disabled user significantly, thus helping to realise the availability of services for anyone, anytime. Including voice input in a traditional web browser may give more flexibility to its operation and may permit the user to continue browsing in a hands-busy situation. Some applications may include pure voice interaction to control a screen with graphical information (e.g. during medical interventions (Grasso 1995). Some other scenarios may completely lack a graphic environment, e.g. telephone browsing or navigating systems for visually impaired users.

Adopting voice technology has met with several technical bottlenecks in the past. First the reliability of recognizers still leaves room for improvement. Nevertheless the current recognizers allow for reasonable use with restricted vocabularies in environments with little or predictable background noise. Secondly, recognizers put heavy requirements on the computing power and memory usage of the computer systems. Nowadays, PCs are equipped with sufficient power, and recognizers have even been implemented in hand-held devices. For small-vocabulary command purposes dedicated one-chip solutions have even been developed. Thirdly, the design of voice interaction is rather complex, due to unpredictable and inaccurate user input, complex dialogue management and the need for special purpose software. This problem has been alleviated by the definition of a standard markup language (VoiceXML) for the development of voice-based applications. Also programming environments have started to provide standardised APIs for speech recognition and synthesis (e.g. Java Speech API). Fourthly, synthesized speech still suffers from unnaturalness. Whenever the number of possible utterances is limited, recorded human voices are still preferred. However, for true flexibility, speech synthesis must be used. Fortunately also here steady progress is being made and several commercially available products are on the market.

Gesture-based interaction

According to (Brewster & Murray-Smith 2000) haptic technology is now maturing and coming out of research laboratories into real products and applications. Haptic interaction is interaction related to sense or touch. This could be based on force-feedback or tactile devices. We can take advantage of our sense of touch as an alternative mechanism to send and receive information in computer interfaces.

Common human-to-human interaction includes a variety of spontaneous and subliminal gestures such as finger, hand, body and head movements. So far, gestures have not really been used in interaction with the virtual world, with the exception of pointing actions often performed indirectly via mouse-like pointing devices (see also next section on physical pointing).

Gestures could be used with personal mobile devices, e.g. to control home appliances with simple user definable hand movements. Simple up-and-down hand movements could be used to control a garage door, the volume of stereo equipment or a room's lights depending on the user's location or orientation. However, since gestures are unfamiliar for this purpose, research is needed to identify the gestures that people find natural and easy to remember for certain control tasks.

Existing research on gesture recognition can be classified into two main categories: camera-based and sensor-based. The camera-based approach is more suitable for stationary applications, which often require a specific camera setup, lighting conditions and calibration. Recent research demonstrates 3D mice (Hinckley et al. 1998), interactive movies (Segen & Kumar 1998) and home appliance control (Fails & Olsen 2002) Georgia Tech's Aware Home project developed a camera-based control device called Gesture Pendant (Starner et al. 2000) allowing the wearer to control elements in the home via hand gestures supported by contextual cues such as location, orientation and speech. Sensor-based techniques utilise e.g. tilt, acceleration, pressure, conductivity, or capacitance sensors to measure gestural movement. An example is GestureWrist, a wristwatch-type hand gesture recognition device using both capacitance and acceleration sensors to detect forearm and hand gestures (Kidd et al. 1999).

Since camera-based gesture recognition has limited support for wearability and mobility, VTT's research has focused on sensor-based solutions (Vehmas et al. 2003).

Physical browsing

The ubiquitous computing vision introduces new challenges for interaction design. One of these is related to the fact that interaction relates to artefacts in the real world, and typical computer based selection of items from a list or menu is too cumbersome to be used. A more intuitive solution for the selection of items to control or services to use is to select them through a physical action like pointing, touching, or just being close to the target. These physical actions significantly aid in dealing with the overload of available services in future smart environments. This particular use of physical actions for selection has been called physical selection, or physical browsing. The latter refers to the complete interaction process, whereas the first refers to the concrete selection technology (Välkkynen et al. 2003).

Ideas close to physical selection have been suggested (Kinderberg & al. 2000, Ulmer et al. 1998, Want et al. 1998) developed the idea of Phicons, which serve as physical icons for the containment, transport and manipulation of online media in an office environment. They use fixed devices, such as digital whiteboards, projectors, and printers as user devices. Kinderberg and co-workers have studied infrastructures to support "web presence" for the real world (Kinderberg & al. 2000), their main idea being connecting physical objects with corresponding web sites. Infrared (IR) beacons, electronic tags or barcodes are suggested for creating the connection.

Gaze

Gaze, i.e. the direction in which one is looking, can be used as a pointing and selection method as well. Gaze can be determined by means of a camera facing the user, a laser beam tracking system, or sensors measuring eye-muscle activity. The accuracy of the tracking method varies and often gaze tracking requires the user to be at a predetermined location. However, also systems integrated into wearable displays have been proposed.

Gaze-directed systems seem to have found applications in military systems, as aids for handicapped people, and as a tool for attention research. Otherwise, their use has been rather limited due to the special equipment needed and the limited mobility. Also, since gaze is primarily used to input information, the multimodal role of gaze may be difficult to adopt for users.

Distributed user interfaces

Increased use of mobile services and the AmI vision have given rise to remote and distributed interaction paradigms. Instead of operating a device directly by means of a dedicated and integrated user interface, user interfaces may be removed from their target devices and two-way interaction with services can take place anywhere. This has major effects on the design of user interfaces. Since the physical properties of the user interface may vary due to different terminal devices and available modalities, the user interface must be developed in a much more flexible way. Adaptation is a key word in this branch of research. User interfaces may be rendered differently depending on the device used for rendering, but the provided functionality will often be the same. Also the fact that the user interface is remote and operates via a (wireless) network connection affects the architecture of the user interface.

This trend towards a separation of the functional part operated by the user interface and the user interface rendering device and/or software platform affects the whole design cycle for user interface software. The requirements analysis phase needs to take into account that the system may be used through different terminals and in a variety of contexts. The design phase must provide a solution for a variety of physical renderings of the user interface, including several alternative modalities, or adopt a smart adaptation methodology to cope with the variety of renderings. The software architecture must take into account the properties of different networking solutions and the processing power of terminal devices and possible intermediating proxies. The user interface server must deal with unreliable and possibly slow connections and multiple users. The user interface rendering device will have to be able to communicate its features, preferably be flexible in the rendering formats and communication channels, and be able to fine-tune the final rendering through adaptation.

The design of mobile user interfaces, especially for graphics adaptation, has been researched extensively. A task-based design methodology has e.g. been proposed (Paternò & Santoro 2002). Also different models to describe a user interface in generic terms so as to aid in the adaptation process have been proposed (Abrams et al. 1999, Puerta & Eisenstein 2002). Middleware architectures take into account the need for distributed user interfaces

This branch will benefit significantly from standardization of the user interface description and distribution mechanisms and the availability of tools for design and adaptation. In spite of efforts in this area, consensus has yet to be reached.

6. Design drivers

6.1 Fast, complex and concurrent design processes

Current software engineering methods are based on system modelling whereas human-centred design is based on prototyping. This basic difference in approaches is an obstacle to adopting human-centred design in software engineering (Gulliksen et al. 2003). Anttila et al. propose a ladder method for stepwise software engineering (Anttila et al. 2003). This method integrates stepwise feature introduction with human-centred design methods. The development work is done stepwise, so that intermediate releases of the software include a growing number of readily implemented features. Each stepwise release can then be modelled, implemented and evaluated independently.

Pekka Ketola points out challenges to the human-centred design approach in the concurrent product development of mobile phones (Ketola 2002). Current mobile phones are equipped with many new features like cameras, radios, email and mobile web. The products, as well as the development processes, are getting increasingly complex. Simultaneously, the time to market is getting shorter and the target user groups are increasingly heterogeneous. To speed up the time to market, development processes are divided into concurrent design activities that are integrated together as the design proceeds. To keep the process under control, design decisions need to be fixed at certain milestones. As the entity of the product is put together as the first functional prototypes, many issues are already fixed and cannot be changed based on user evaluation results. There is a clear need to get reliable user feedback earlier in the development process as well as enhancing human-centred design methods so that they can be applied in concurrent product development.

As individual products become ever more complex, so do the infrastructures around them. Mobile phones, televisions and other everyday equipment increasingly utilise network connections via which users have access to different services. The human-centred design approach should be applied to the entities of different devices, networks and services. Again, concurrent usability design methods should be developed to cope with this challenge.

Anu Kankainen presents thinking models and tools that would help in understanding user experience related to information appliance product concepts (Kankainen 2002). User experience prototypes are called "probes" in her work, and the concept is built on the cultural probes presented by Gaver. Users themselves can create usage scenarios by using the probes. Thus users can participate in the design rather than just assess ready-made solutions.

6.2 Design and evaluation methods meet their limits

As described in Chapter 2, contextual design and the human-centred design approach as such emphasise understanding the contexts of use. Consumer applications can have various contexts of use, and a mobile user can use his/her mobile system in several different contexts. Applications and services can even identify the current context of use and adapt their behaviour accordingly. This constitutes a major challenge for human-centred design.

With consumer products, heterogeneous user groups and the varying contexts of use force designers to choose key user groups and key contexts of use in the design, because all possible contexts with all possible users cannot be studied. Decisions on the target user groups and contexts have to be made early in the design and may thus forget essential user groups. Thorough user studies should precede the actual design process, so that design decisions are based on thorough understanding of the users, their everyday life and existing and evolving usage cultures.

New technologies often present challenges to design, because they may not be improvements to existing devices, offering instead potential for new practices. Designing something completely new is not something current usability practices are particularly good at, and our design methods may be badly defective in this respect.

Pervasive computing will fundamentally change the way people use computing devices to perform their tasks. There is a need for effective methods for creating, illustrating and evaluating usage scenarios enabled by pervasive applications (Sotamaa & Ikonen 2003). The methods should be able to handle the dynamic nature of usage situations, device heterogeneity, resource availability and widely varying social environments (Leikas et al. 2003). When designing multimodal user interfaces, instead of visualising user interface solutions for users, more versatile illustration methods will be needed.

Traditional laboratory experiments have their limits and cannot capture the rich nature of the usage environments (Banavar & Bernstein 2000). Usability evaluations need to focus more on field trials, both to have access to the necessary technical infrastructure and to be able to observe real usage in real contexts of use.

Current usability design practices are targeted to the design processes of individual products. In the future, emphasis will be on service entities where several computers communicate together and with the user. These entities will require different methods for human-centred design because of their complexity.

Problems in predicting the needs for usage in design have also been tackled in the user-centred design of industrial ICT systems. A promising design approach was recently introduced by Kim Vicente in his book on cognitive work analysis (Vicente 1999). This approach is based on the system-oriented cognitive engineering research tradition created by Jens Rasmussen and colleagues at Risö National Laboratory in Denmark (Rasmussen 1986). The approach aims at facilitating the design of complex sociotechnical systems with the aid of a formative design framework. The framework is aimed at providing sufficient flexibility in design and adaptation to meet the unpredictable demands of the future usage of the final product. This methodology does not focus on specific user actions or tasks. Instead it focuses on modelling of the intrinsic constraints of the domain, i.e. the physical and social context and object of these tasks. Such a modelling approach is coined formative modelling. It focuses on the critical boundary conditions of the domain. These are demands that shape user actions as possibilities and constraints. They must be taken into account in the design of artefacts. Such orientation in interface design is the concept of ecological interface design (EID), which is currently drawing much interest, and different approaches have been suggested (Flach et al. 1995, Vicente 2002).

6.3 Introducing new products into use

The adoption and use of information technology is a central concern in many organisations, because new products are often underutilised. The Technology Acceptance Model (TAM) is a fairly widely adopted tool for explaining and predicting user acceptance of information technology products at work (Davis 1989). According to TAM the effect of external variables (system characteristics, training etc.) are mediated by perceived usefulness and perceived ease of use. Perceived usefulness and perceived ease of use are the two most important factors in explaining system use. TAM has been applied mostly in studying office software usage, and in that field the model can explain about 40% of system use (Legris et al. 2003). Venkatesh and Davis have updated the model to TAM2, which provides a detailed account to the key forces underlying judgements of perceived usefulness, explaining up to 60% of the variance in this important driver of usage intentions (Venkatesh & Davis 2000). TAM2 showed that subjective norms significantly influenced perceived usefulness, via both internationalisation (social influence on the user's own usefulness perception) and identification (gaining status and influence within the work group). TAM was originally developed for studying technology at work. In VTT's studies it has successfully also been applied for studying user acceptance of consumer products.

Consumer products target a very wide market. Written instructions are often out of the question because people expect to be able to take consumer products into use without consulting manuals. Schoeffel claims that current consumer products are such that 0–95% of users can use them intuitively (Schoeffel 2003). If the percentage falls below 50, producers normally notice that there is a problem due to the number and anger of users searching for help. However, things are moving in a better direction; without the success of designing for usability, e.g. the Internet revolution would never have been possible. ISO is currently defining a standard for the usability of everyday products, ISO/CD 20282 (Schoeffel 2003). The standard will present an instantiation of the ISO 9241 standard series that was originally designed for office systems. The aim of the ISO/CD 20282 standard is to ensure ease of operation for everyday products marketed globally.

Current mobile devices exhibit a high heterogeneity of hardware and software capabilities, operating systems and supported network technologies. This heterogeneity does not just cause problems for service providers but it also significantly increases configuration hassles for device users (Bellavista et al. 2002). Device manufacturers and other actors have tried to ease the situation by different standardisation activities, and by providing open platforms for easier service creation and application interoperability. However, user and marketing needs still require diversity.

The initial experience that a user has in taking a new product out of the box and setting it up, in preparation for use, creates a lasting impression of the product, which constitutes an important aspect of the total user experience. IBM has prepared guidelines on how to design out-of-box experiences that are productive and satisfying to users. They also provide suggestions for effective evaluation and testing of the out-of-box experience (IBM 2003).

VTT's studies of the introduction of digital television in Finland revealed that users had many wrong impressions of the new technology. The marketing messages emphasised issues that were not yet available in the first commercially available set-top boxes. The marketing emphasised easy installation, which was more or less true with the set-top boxes themselves, but forgot to mention problems the user might face through an incompatible or misdirected aerial. On the other hand, marketing messages did not emphasise better image quality, which most users considered the main benefit of digital television (Kantola et al. 2003).

VTT's studies on mobile Internet and mobile multimedia messaging also identified several issues regarding which users had missing or wrong information about the new service (Kasesniemi et al. 2003, Kolari et al. 2002). Many users had quite a blurred understanding of the features available on their own mobile phones. Some users had a wrong conception of the services behind the given acronyms (e.g. MMS). The possibilities and restrictions of different network technologies were unclear to many users (e.g. Bluetooth). Not all users understood which features and services were readily available on their phone and which features they had to install separately. It was not clear either where to find the instructions for installation. And finally, users did not always understand the installation instructions. All this lack of information constitutes quite an obstacle to taking mobile services into use.

When WAP phones were first released onto the market, users had to make the installations manually. This required up to twenty or more steps, which most likely prevented most users from taking the services into use. Nokia originally developed a technique with which the configuration can be sent to the phone as smart messages (over the air, OTA). When receiving the message, all the user has to do is reply "yes" to the question whether the configuration included in the message should be taken into use. Other phone manufacturers have adopted this technique as well and it clearly eases installation. However, the user still has to find out which message to send and where. Often the motivation to get services into use is not high enough to bother finding out how to order the configuration.

Personal configuration, for instance email settings, is more difficult to automate. However, there are already solutions for this as well. For instance, SonyEricsson and Nokia provide a Web interface from where the user can select the country and preferred Internet service provider. After entering one's user name and password, the system sends the user a configuration message with all settings for the email account.

In their study of the needs of active elderly people for mobile phones, Tuomainen and Haapanen found that usage support was more crucial than ergonomics (Tuomainen & Haapanen 2003). Maguire and Osman also point out the need for new, innovative ways to learn to use mobile phone functions (Maguire & Osman 2003). It is important for any user to get understandable information about available services and guidance in installation and usage.

Context-aware services raise additional challenges for taking the services into use. The services may be available only locally or in certain contexts. The mobile user should easily find the available services in his/her current surroundings, and get information on what functions the services provide, on how to use the services, and on possible limitations of the services. The user should then be able to take these services into use easily, and use them thereafter (Kaasinen 2003).

Ikonen et al. suggest a trade description model that can be used in making sure that users get the necessary information about new products when the products are introduced onto the market and when the users make their purchasing decisions (Ikonen et al. 2002). The model includes a list of questions that users will need answers to, classified as questions related to who can use the product, where the product can be used, what kind of additional equipment is needed, what the user can do with the product, and what are the special features of the product. Ikonen et al. suggest that the answers to questions are easier understood if they are given in the form of short stories that describe concrete and familiar situations where people are using the product.

6.4 Managing risks to safety and operability

Safety and reliability are still mainly studied in connection with industrial and transport systems. As technology becomes increasingly embedded in our everyday environment, and as we become ever more dependent on technology, safety and reliability are gaining increasing importance also in the design of consumer products.

The key functions that facilitate safety and operability include:

- Sensing and data acquisition
- Signal processing and feature extraction
- Production of alarms or alerts
- Failure or fault diagnosis and device health assessment
- Prognostics: projection of device health profiles to predict future health or estimation of RUL (device's remaining useful life)
- Decision reasoning: maintenance recommendations, or evaluation of asset readiness for a particular operational scenario
- Management and control of data flows or test sequences
- Management of historical data storage and historical data access
- System configuration management
- Human system interface.

Future factory equipment and facilities will have predictive maintenance with self-correcting capability, and will communicate throughout the extended enterprise to provide reliability, maintainability, and other data to support efficient factory operations and maintenance. Processes, equipment, and facilities will be reconfigurable, based on real-time models that trade off options for best solutions based on product volume and mix, model changes, and facility upgrades. Control systems will automatically optimise operations based on product throughput, process and facilities maintenance, environmental friendliness, worker health, and energy usage. The control models will monitor the status of various resources, factoring in shop-floor economic considerations, and predicting or planning needed maintenance operations. In many factories, human intervention will be required only to handle unplanned events.

Optimisation of the availability of all processing equipment and facilities requires the development of robust, integrated predictive maintenance systems that use a variety of technologies to enable predictive maintenance to avoid downtime. Some specific technologies include:

- *Distributed Diagnostics Access:* Develop procedures to make equipment and facilities diagnostic data available locally and to the equipment manufacturer.
- *Maintenance History Knowledge Base:* Develop standards and specifications for creation of maintenance knowledge bases to build better equipment and facilities.
- *Interactive Help Systems:* Develop systems that provide interactive, context-sensitive help for maintenance and operation of equipment and facilities.

The development of self-healing and self-correcting systems provides autonomous identification of modules likely to fail, and automatic spare parts/material ordering to avoid equipment and facilities downtime and reduce maintenance lead times. Under such conditions, appropriate corrective actions can be taken in a timely manner.

An important domain of managing risk in complex systems is human reliability. The target of ensuring reliability and safety of human performance and of promoting organisational structures that support reliable behaviour is a major goal of design. There are a number of important areas that must be covered in a complete human-reliability-informed design process. According to Kirwan (Kirwan 2003) these domains comprise:

- Allocation of function
- Person specification
- Staffing and organisation
- Task and interface design
- Training and procedure support
- Human reliability assessment.

A common saying among human factors states, "If you consider human factors too expensive, try an accident." This saying elaborates the major motivation to carry out extensive human factors programmes in reliability and quality critical organisations and systems. However, it is not easy to give evidence of the economical benefits of such programmes. In so-called high reliability organisations, a risk-informed approach is necessary. It requires that the management of such organisations comprehends the problems conceptually, accomplishes necessary risk assessments, and takes the responsibility to act proactively with the aim of developing competencies to cope with the risks (Schulman 1993). Some results of the efficiency and production effects of training and development programmes are available (Seppänen 2003).

While there still is resistance and other obstacles within the design communities of various countries to include human factors in the design for safety and operability, there are also good results from some leading countries such as France, England, the US and Japan. Kirwan concludes that human-centred design has become the norm due to the operability and safety problems of ignoring the human element. He also maintains that interaction among designers, human factors specialists and operators is necessary to get the design right (Kirwan 2003).

6.5 Environmental and clean technologies

Sustainable growth requires an improvement in the environmental efficiency of products, processes and activities. Consumers are becoming more aware of the environmental effects of the products they buy, therefore business ethics play a growing role in attracting increasingly conscious and selective customers. Responsible environmental stewardship is becoming an increasingly astute business decision.

Waste-free manufacturing will require design methods that consider the total life cycle of a product. Environmentally conscious manufacturers will evaluate waste production and recycling at each step of the conversion process, considering all process waste and by-products as "raw material" for other processes. Environmental management will take advantage of advances in distributed information technologies. Innovative process technologies, such as net-shape processing, bio-processing, and molecular self-assembly, could produce products with unique properties and characteristics and generate very little waste.

Processes optimised for near-zero waste often also require less energy. Ideally, the efficiency of mechanical energy and process heat will be maximised and the lost energy recycled, converted, or transferred to supplement the energy requirement. Particular attention should be directed toward recovering the immense amount of heat energy lost from metal processing furnaces, welding processes, coolants, transformers, compressors, condensers, and distillation columns.

Ambient intelligence embeds computing power everywhere in our environment. Techniques to remotely recharge power to embedded equipment will be essential for creating environments that can be easily maintained. Devices will be increasingly mobile, and as people become increasingly dependent on their mobile devices, low power consumption and ease of recharging will be essential.

7. HTI challenges

In this chapter we identify the most important research challenges regarding human-technology interaction. The challenges emerge from the tensions of the information society, which were analysed in the previous chapter as the drivers of development. Our systemic concept of HTI will be used in structuring these challenges.

At the beginning of this report we made a distinction between the three levels of HTI: the interface, the task and the organisational level. This conception of interaction may be grounded on the hierarchical conception of activity developed by Leont'ev, one of the central figures of the cultural-historical theory of activity (Leont'ev 1978). This theory provides the possibility to comprehend specific HTI problems in connection to each other. It proposes the notion that human interaction with the environment is mediated by artefacts and concepts. These are instruments of action and provide the possibility for the control of interaction. According to the theory, this interaction should be analysed on different systemic levels, as situationally constrained operations, goal directed actions, and as societally defined activities of organisations. The holistic context that the activity system provides is significant because it enables understanding of the societal meaning of various tasks people are performing and the significance of the physical and technical affordances that constrain the immediate operations of people in work and everyday tasks. The hierarchical model of activity of Leont'ev has been adapted to the human-computer interaction field by various investigators (Bertelsen & Bödker 2002, Bödker 1991, Kuutti 2003, Kuutti & Bannon 1993). Our systemic HTI concept draws on the cultural-historical concept of activity and is depicted in Figure 14.

The three interaction perspectives of our systemic HTI concept are derived from the multi-levelled concept of activity. The perspectives are "smart objects, services and environments", "usage practices and competencies", and "culture and organisations". These perspectives are depicted in Figure 14 as interlinked aspects of interaction. Enabling technologies is the notion that is used for the set of available technologies for HTI. As these technologies have the function of mediating human-environment interaction they are depicted in the centre of the figure. Realisation of the mediating function of technologies manifests itself in different ways depending on which level of activity we choose to analyse interaction. In the beginning of this report we mentioned that HTI has a product and a design aspect. The three interaction perspectives and the enabling technologies refer to the product aspect of HTI.

The design aspect of HTI is also depicted in Figure 14. Human-centred design is an activity that focuses on all three aspects of interaction and develops the mediating enabling technologies according to the needs of this interaction. In any real-life design, each of the three aspects of interaction is treated in one form or another, as a focal research question or a context to be taken into account.

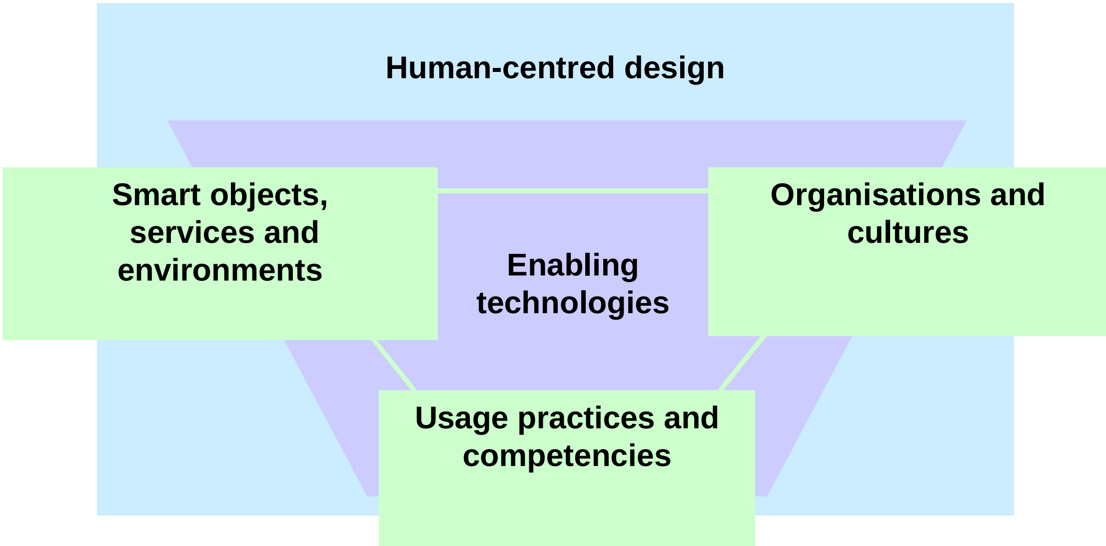

Figure 14. The HTI research domain.

The systemic notion of HTI provided us with the big picture of the HTI research domain. It served as a conceptual tool when we comprehended and classified the HTI research challenges that we could derive from the societal, technical and design drivers. As a result of our conceptual work we identified 25 HTI research challenges. These were assigned to one of the five elements of our systemic HTI model. The research challenges are listed in Table 5 and described in the following sections 7.1 to 7.5.

Table 5. Overview of identified HTI research challenges. The challenges are relevant to each of the domains covered in this report, i.e. in everyday life, systems of production and transportation.

Enabling technologies

- Wireless world
- Information management
- Ambient intelligence
- Context awareness
- Personalisation
- Multimodal user interface technologies

Interacting with smart objects, services and environments

- Information and services available anywhere and anytime
- From information overflow to contextually relevant knowledge
- Our surrounding is the interface: very personal and extremely global
- Personal mobile device is a tool to orient within and interact with the environment
- Natural, intuitive, easy, simple and friendly interaction

Usage practices and competencies

- Designing distributed cognitive systems
- Keeping the user in control of technology
- Promoting adaptive user practices and lifelong learning
- Introducing new products into use
- Ensuring safety and operability

Organisations and cultures

- Establishing Design for All as a practice
- Understanding organisational and usage cultures
- Understanding and managing innovation processes
- Ethical assessment of new technologies

Human-Centred Design

- Usage and design form a synthetic creative process
- Continuous connection to users
- Involving all actors of the value network in the design
- Coping with concurrent and distributed design environments
- New technologies require new HTI research methods and offer new forms of collaboration

7.1 Enabling technologies

7.1.1 Wireless world

Challenges for the development of technologies for the wireless world can be found in different flavours of wireless connections, support for ad-hoc connectivity, management of a very dynamic set of connections, and accommodation of a great variety of devices. While operators dominate the developments for public telecommunication networks, the use of short-range wireless communication, e.g. BlueTooth, offers an attractive alternative for wire-replacement and service selection. In addition to the challenges posed by taking this new technology into use, challenges can also be found in the development of alternative short-range wireless technologies that tackle BlueTooth problems like power consumption, range selection, complexity, cost, etc. Potential candidates are e.g. UWB, ZigBee and RF-tags. The latter may be passive or operate on parasitic power in order to minimise size and power consumption.

On a higher layer of the communication stack, challenges can be found on the middleware level. Management of dynamically changing communication channels and ad-hoc connectivity to terminals and devices with different features require new solutions. Also service discovery in a changing environment poses its own requirements to the system. Standardisation efforts in this area are very important to guarantee the kind of interoperability envisioned in a wireless future.

7.1.2 Information management

Managing the growing amount of information available on-line via wireless or wired networks requires technologies that enhance the information with meta-data and methodologies to help the user find the information relevant for him/her at that moment and in his/her current context. Formats for meta-data description exist, but the content of the meta-data is hardly standardised and often missing due to the laborious process of annotating information. Ontologies – enhanced concept dictionaries – can alleviate this first problem, but their proper definition and use is a challenge, particularly because of the lack of a commonly accepted ontology format and the difficulty to find a trade-off between a sufficient domain-specific ontology and a huge (expensive) general purpose ontology.

Manual provision of meta-data is often cumbersome, and there is a great need for the automatic provision of meta-data for documents and multimedia. Word-spotting techniques can be used in documents and conversations, while feature extraction is used with audio and video data to provide hints on their contents. Also non-semantic methods can be used to search for “similar” data in a limited collection, using intelligent search techniques and e.g. neural networks. More research is needed on how to use intelligent methods for this purpose, and on how to apply methods applied by web search engines in personal data management.

7.1.3 Ambient intelligence

Technologies needed for the realisation of the ambience intelligence vision include those needed for ubiquitous computing, ubiquitous communication and natural user interfaces. Challenges related to natural user interfaces are described in Chapter 7.2.6, while some of the challenges in ubiquitous communication are mentioned in 7.1.1. Ambient intelligence is enabled by ever smaller and more powerful computing hardware, thus placing requirements on the miniaturisation and form factor of the hardware. Simultaneously the increasing number of computing devices in everyday artefacts means that costs and power consumption must be very low.

Facilitating interoperability is the main challenge for large-scale implementation of ambient intelligence. Standardisation activities will be needed to facilitate ad-hoc networking and communication between several different objects globally. Furthermore, intelligent solutions are needed to make the distributed parts of the system work together purposefully and to make the system aware of its environment and user.

7.1.4 Context awareness

Establishing the context of a user and using the context for adapting services often needs advanced technologies that combine information from several sources and provide the resulting context estimation in an agreed format to the application or service. Positioning has received the most research attention as a context-providing technology. Good solutions exist for outdoor positioning, but indoor positioning is still a challenging field of research. Solutions range from wireless triangulation methods to the use of proximity to RF-tags. Deriving context cues from sensor-based information is a challenging field of research. Sensors embedded in the environment and the user's mobile devices can be used to gather raw data about the environment's lighting, temperature, audio scene, movements, etc., but also about the user's physiological condition. Processing this data to extract features and combining the provided cues with other context sources is a complex task.

The use of context by applications needs to be facilitated through clear standardised formats and APIs to communicate this context information. Also the use of context information for application and service adaptation needs to be studied and will eventually result in new methodologies for adaptive service design.

7.1.5 Personalisation

There is a need for personalisation techniques that do not require too much effort from the user. Bio-identification methods will be used increasingly to avoid needless login procedures and provide a higher level of security. Bio-identification technologies differ in their level of maturity and research is necessary on the basic and application level.

User modelling includes methods to describe information about a user formally. Since manual definition of this information is often not feasible, research is done on how these models can be updated by unobtrusively observing the user. Models may be based on human-readable discrete semantic information, or on an abstract internal model that can only be used in combination with a dedicated algorithm.

Recommendation of services, or adaptation of services based on the information incorporated in the user model, is guided by intelligent algorithms that match the model with metadata about the service or its contents. When the model includes more than just a list of key-words, matching becomes complex and new methodologies are needed.

7.1.6 Multimodal user interface technologies

Research on technologies for multimodality has concentrated greatly on allowing for interaction with mobile devices or direct interaction with one's physical interface. These technologies have often been summarised as post-WIMP interfaces. In addition to the need for separate research on the improvement of recognition techniques for e.g. speech and gestures, also new design paradigms taking into account multiple modalities and automatic adaptation need to be developed. Mobile devices continue to pose a great challenge, since their limited processing power and physical dimensions require creative solutions to provide a reasonably comfortable level of interaction and deal with the growing amount of information accessed and managed by these devices.

The use of gestures is a somewhat new topic. The lack of tradition in this field necessitates the definition of gesture vocabularies and wide usability studies. Enabling technologies include camera-based solutions, that are less suitable for mobile use, and sensor based solutions. The challenges are similar to those in speech recognition, but also user acceptance and user requirements in different usage contexts are important research topics.

Interaction with the real-world mediated via hand-held or embedded devices needs methods to identify the target of interaction. Pointing seems a natural solution to this problem. Several options exist for the implementation technology, each requiring a different level of environment enhancement (visual tags, optical tags, RF-tags). Research on both the implementation technologies and the usage concepts of these techniques is necessary.

Allowing the use of different modalities and devices with varying properties (e.g. display size) requires techniques for the definition of abstract user interfaces and technologies for the adaptation of these interfaces to the target environment rendering the interface. Several proposals have been done for user interface description, but none has yet achieved an accepted level of standardisation. Research is needed incorporating the whole process of user interface definition, description, adaptation, delivery and remote operation in order to cope with the requirements faced by this approach.

7.2 Interaction with smart objects, services and environments

7.2.1 Information and services available anywhere and anytime

The variety of user devices and technical infrastructures is continuously growing. The use of services is no longer limited to a particular location or device. Instead, services are being accessed via wireless and wired connections from wherever the user resides, using the devices and technical infrastructures available to the user. Users need to communicate with people and information related to their tasks, not just those with compatible equipment. That is why services need to be designed for multi- and cross-platform use; the contents and the presentation have to adapt accordingly.

The services should adapt according to the context of use: the device, the technical infrastructure, the user and the usage situation. The user may have several different devices in use and (s)he should be able to transfer his/her tasks and information between those devices, even in the middle of a usage situation.

A concept proposed to allow mobile users to create a familiar environment for themselves wherever they are is called “virtual home”. The user will be able to personalise access to locally available services by means of user profiles and background information on his interests and accustomed use of services.

7.2.2 From information overflow to contextually relevant knowledge

Semantic web and other technologies provide ways to refine information to knowledge, providing the user with not just access to information but relevant information and functionality, adapted according to his/her usage context. There is a great amount of information available, e.g. via the Internet, which is unfortunately hardly ever structured or enhanced with so-called metadata (information about information – see also 7.1.2). Metadata may be generated partly automatically by means of intelligent algorithms that scan content, but often also manual addition of metadata is required to achieve a sufficient level of detail. To get full advantage of metadata, both the service providers and end users should be equipped with relevant tools.

Combining the information in the meta-data with information about the context (7.1.4) and the user (7.1.5) allows for services that are able to provide relevant information by filtering irrelevant information or recommending content.

In the domain of complex information and control systems, new integrative approaches are currently being sought to aid operators orient themselves and navigate the massive information flow from complex systems. The problems currently being tackled may be expressed under two main headings: task adaptation and information synthesis. Different new approaches, such as flow model presentation and ecological displays of functional displays, are currently being developed to synthesise available information and to improve its comprehension.

7.2.3 Our surrounding is the interface – very personal and extremely global

Future information technology will be increasingly ambient, providing users with ubiquitous computing, ubiquitous communication and intelligent user-friendly interfaces. Computing power will be integrated into different everyday objects and the smart objects will be able to interact with each other and the users. The ambient environments should be very personal: aware of each individual user and the usage context, and capable of responding to user needs intelligently. At the same time the environments will become global: available everywhere and for anyone.

Ambient intelligence should provide users with meaningful technology entities that give them information about their environment, adapt the technology according to their context of use, and let them feel and be in control of the whole. The user should easily get an overview of the ambient environment when getting there: what is available and how it can be utilised. To feel and be in control, the user should be able to understand the reasoning behind the proactive and automatic behaviour of the environment.

7.2.4 Personal mobile device is a tool for orienting in and interacting with the environment

Future mobile devices will not just be entities in their own right, but they will become mediators for orienting in, and controlling, a complex environment. The devices will need to adapt seamlessly to the available network infrastructure and to other technical infrastructures that surround them. The HTI challenge is to give the user information about the available services around him/her and to adapt the user interface accordingly.

The traditional approach to HTI is based on the insight of the human being as one entity and the machine as another. These entities communicate through a well-defined human-computer interaction channel. In ubiquitous environments, however, HTI is no longer that simple. The user may simultaneously communicate with several devices, the devices may communicate with each other, and the situation may involve several users, either locally or remotely.

While the available services, applications and features of mobile devices keep increasing, user interface restrictions still remain: modest input techniques, small screen size, limited computing power and limited network bandwidth. Showing information on small screens is cumbersome and needs innovative solutions utilising e.g. structured text. Text input can be eased by text prediction, ready-made selection lists and context-awareness in the user interface. Alternative input modes, like the use of speech, are not yet technically mature and users are not willing to use speech input in all usage contexts (see also 7.1.6).

7.2.5 Natural, intuitive, easy, simple and friendly interaction

Natural interaction refers to a comfortable, intuitive and non-obtrusive way to use services, often mimicking inter-human interactions. Truly natural interaction will allow people to use the services intuitively, even without prior training. Current WIMP interfaces utilise only part of the modalities available in human interaction. Particularly speech, hearing, gesturing and gaze are extensively used in human-human interaction and are serious candidates to enhance future HTI.

Natural interaction is only possible when the services are made smarter, or more aware. The service should recognise its user, know his/her background and understand how the context affects the user's expectations towards the service. Furthermore, the interaction should preferably use the most natural modalities and interaction channels (devices, terminals) available for the interaction (7.1.6).

New, post-desktop, user interface metaphors will be needed especially for mobile use. There may be needs for sets of metaphors, each tailored to a specific application or a specific information type. Novel user interfaces may require learning or even teaching from users. It should be studied how the new solutions could replace existing ones in practice. Being increasingly integrated with the human user, safety, reliability and acceptability are important research themes of novel UI solutions.

Taking new modalities into account must be facilitated. Designing a WIMP interface has greatly benefited from the established GUI widget concept and the design tools. Similar support is needed e.g. for speech and gesture interfaces and context-providing sensors.

The use of new modalities can either be a necessary replacement of an existing modality that is not available or cannot be used in a certain context, or it can be an alternative modality that can be used at the user's own discretion. Depending on the context, the user may choose to use different options for interaction. For this purpose the UI design must be flexible enough to accommodate such on-the-fly changes in interaction modality.

7.3 Usage practices and competencies

7.3.1 Designing distributed cognitive systems

The new information technology significantly changes our constraints and possibilities for orienting in and making sense of our complex, dynamic and uncertain surroundings. Important for design are issues of how people perceive and comprehend the world, what features of the environment are significant in different tasks, and how to facilitate the perception of the world. We also need to understand the constraints of communication and organisation of collaboration.

The technological steps that have been taken in ICT with regard to the enabling technologies may appear to effectively push the change in our ways of conceiving cognition and action. These new appliances, wearable or smart objects and proactive environments demonstrate in a concrete way that the environment is part of our being in the world, and that cognition is distributed and embedded in the environment and in our physical body. Smart objects and environments should be studied as prototypes for even more complete forms of exploitation of the possibilities of ICT. Hence comparative interdomain research on the use of smart objects is needed for understanding the possibilities and constraints entailed in these technologies.

7.3.2 Keeping the user in control of technology

Technical infrastructures are becoming increasingly diverse and embedded everywhere around us. Smart environments aim at automatic functioning, so that the user does not have to intervene. However, in order to intervene when necessary, users need to understand the reasoning behind the behaviour of the environment.

It is necessary to improve the informativeness of information presented to the user. Informativeness is always connected to the purposes and intentions of the actors. This creates the need for understanding tasks that people are involved with. A further challenge relates to the forms of presenting information. The construction of connections between signs and their referent objects in natural task performance still needs to be discovered. Through the presentation of the information array we fundamentally affect peoples' situation awareness and possibilities to act on issues that affect one's control of the situation. Ecological design principles, i.e. those that facilitate comprehension of the environment via direct perception, should be sought. Innovations in ecological design are expected to reduce the need for seeking and processing information that is often provided in serial form in current information systems, and to reduce unnecessary mental strain.

Smart systems should also be predictable and self-explanatory. The user should get necessary feedback from his/her actions to understand the reasoning behind the behaviour of the environment. An important further research and design challenge is to understand the mechanisms of the formation of confidence in technology. An appropriate balancing between procedural control and the actors' own internal control, that is based on expertise in the task, should also be facilitated.

7.3.3 Promoting adaptive user practices and lifelong learning

Adopting new technologies into everyday use always requires considerable learning efforts from users. Within the context of future HTI research, learning processes should be tackled from divergent points of view.

In order to improve integrated management of production processes over their life cycle, enterprises are widely implementing industrial ICT. These improvements in the industrial ICT induce changes in the competence demands of personnel. Mastery of work requires that workers comprehend wholes, dynamic phenomena, lifecycles etc. This assumes conceptual mastery of the production process. Research issues for the future include theoretical understanding of the nature of operatively effective concepts and their relationship to formal scientific or engineering knowledge. It is also necessary to develop methods for evaluating conceptual mastery of complex work domains.

Organisational learning should be facilitated, and empirical research should be accomplished to reveal the nature of innovative processes on the shop floor. Methods for analysing practices should be developed. The evaluation of the appropriateness of user practices creates a major practical, methodical and theoretical challenge. Even in daily routines, practices that are qualified with interpretative operations appear to facilitate coping with the task and to promote learning in work. Different kinds of simulation methods should be implemented for improving work process learning. These methods could also be helpful in collecting operational experience and revealing the contents of tacit knowledge to be mediated for the younger workers of the next generation.

7.3.4 Introducing new products into use

The initial experience a user has in taking a new product out of the box and setting it up, in preparation for use, creates a lasting impression and constitutes an important aspect of the total user experience. Taking a new product into use requires several steps. Failing in any of them prevents the user from ever actually using the product. The user should get reliable information about the product to be able to assess whether it could be suitable for him/her and his/her needs. In addition to technical specifications and lists of features, users would need information on usage possibilities as concrete descriptions of how the product would look and feel in their everyday life.

Ubiquitous computing sets additional challenges for designing the introduction and installation of services. Some services are available only in certain contexts and the user should be able to identify, understand and take into use new services easily while on the move.

Management of implementation and modernisation processes in work and large production systems create diverse HTI problems that often have safety relevance. Hence, the advantages and possible drawbacks of changes may have to be evidenced. Methods for managing such global design and implementation processes and understanding their implications for the competence demands of personnel deserve attention in HTI research.

7.3.5 Ensuring safety and operability

The integration of information technology in our environment sets increasing requirements for the safety and reliability of technology. The user should be aware of the issues of reliability and risk before he/she can decide in what circumstances to rely on the technology.

In the design, different usage contexts should be analysed, and safety as well as reliability requirements should be set and evaluated accordingly. New tools and methods should be made available to tackle HTI issues relevant to the safety and operability of complex systems. The methods should compensate for the limitations of present methods, in which human performance is often treated in a prescriptive way. The adaptive abilities and resources for recovery that competent and skilled people have should be acknowledged in the new methods. The cultural processes that shape human individuals and social performance should be taken into account. As part of evaluating good practices and culture, it should be necessary to consider whether these practices are core-task informed. In high-reliability domains this also means that practices should be risk-informed. The results of analyses of human factors and human reliability should be included in the human-centred design of information and control systems.

7.4 Organisations and cultures

7.4.1 Establishing Design for All as a practice

"In a fair society, all individuals would have equal opportunity to participate in, or benefit from, the use of computer resources regardless of race, sex, religion, age, disability, national origin, or other such similar factors." (ACM 2003)

The goal of universal usability or design for all is far-reaching, and immediate action is needed to begin achieving it. Lacking that action creates an increasing "digital divide" – a growing inequality in people's access to technology and the benefits it can bring. Contrary to the fears of sceptics, designing for many different kinds of users often leads to superior design for all users, not lowest-common-denominator designs (Shneiderman 2001).

Concrete actions within individual companies and organisations are needed to adopt the design-for-all principle in such a way that the approach has real influence on their products. On the one hand, different user groups should be included within the design process and no user group should be ignored without good reason; on the other, user groups that would especially benefit from the new technology should be strongly represented.

In the first place, the product should be designed in such a way that it is suitable as such for all users. The product should include adaptive features so it can be adapted to the needs of those users who cannot use the product as such. Designing specific products for specific user groups should be a final option only.

7.4.2 Understanding organisational and usage cultures

The products shape the use, but the use should also shape the products. Technology must support the natural usage patterns of users. To succeed in this, existing and evolving usage cultures should be studied parallel to the technological development. The design must fit the social, technical and environmental contexts of use, and should support existing usage cultures or give users the possibility to create their own, new usage cultures. Ideally, the technology should provide users with possibilities that they can utilise in their own way, rather than forcing certain usage models fixed in the design.

Global changes in working life are also reflected in changing management orientations. Strong foundations and mechanisms are needed for establishing the most advanced collaborative and network-based industries and organisations. It has been anticipated that in a few years most enterprises will be part of some sustainable collaborative networks that will act as breeding environments for the formation of dynamic virtual organisations in response to fast changing market conditions. Research challenges are emerging in the theoretical comprehension and evaluation of new management strategies, and in implementing new management practices and cultures (ECOLEAD 2003).

The improvement of work-process-relevant competencies of personnel and the organisational culture in industrial organisations has important safety- and quality relevance for production systems and organisations. Furthermore, personnel and organisational development constitute a strategic business factor in competitive markets. Empirical and theoretical research is needed to understand what organisational culture is, how the culture is actually constructed, and what its specific forms are in today’s working life. The research challenges relate in particular to the development of adequate contextual tools for description and evaluation of cultures. Questionnaire methods should be developed and used in integration with qualitative and conceptual approaches that enable interpretation of the quantitative. Developmental processes should be facilitated in organisations by enabling reflection and evaluation of the culture and actual practices. Modelling of the constraints and possibilities of the work domain enables definition of the criteria of the good practice, which according to MacIntyre must be considered from the practice internal perspective (MacIntyre 1984). ITEA Office Association. 2001. Technology Roadmap on Software Intensive Systems. The Vision of ITEA (ITEA 2001).

7.4.3 Understanding and managing innovation processes

Grounded on the present and developing education system in Finland, closer co-operation between science, education and industry is necessary to improve the national innovation system (Science and Technology Policy Councel of Finland 2003). In the HTI context we emphasise empirical research on innovation processes and development of methods for their management.

Improving the empirical basis of innovative processes is most important for better comprehension of the creative mechanism and for implementing innovative cycles. However, empirical research assumes more profound understanding of the technological and scientific basis of the production systems or other complex domains of work. Therefore, interdisciplinary studies that bridge the gap between engineering, social science and economy should be promoted in this area of research.

7.4.4 Ethical assessment of new technologies

Through decisions made by designers and the way products are marketed, certain values become embedded in the products. A key question in the ethics of information technology is privacy: what personal information will be collected and stored, by whom, and how the information will be used and redirected. The basic principle is that the user's personal information should not be collected without the permission and awareness of the user. This applies also to user and usability studies where personal information is typically collected, e.g. in the form of usage logs. Security and trust are also important issues: the user should be aware of the risks in using the product and (s)he should have reliable information to assess how much (s)he can rely on the technology in different usage contexts. Ethical considerations should also include equality; is the product accessible and affordable to those who want to use it, might people who do not adopt the technology be discriminated against, and does the technology worsen the digital divide?

Technology is not ethics-neutral, and its developers cannot leave the responsibility of ethical implications to others. However, it is impossible to ensure that technology is being used solely for the purpose it was designed for. Legislation always tends to be one step behind the technology, so one cannot rely on legislation to take care of all the ethical issues. Ethical assessment should be integrated as a vital part of the technology design and development processes. Key ethical issues should be raised in public discussion.

7.5 Human-centred design of HTI

7.5.1 Usage and design form a synthetic creative process

Design and usage processes form one unbroken and continuous cycle. Usage is incorporated with design in various ways during the lifecycle of the product. Users should not be viewed only as resources for the design process; they are designers primarily through their usage.

In addition to incorporating users better in the design process, we also need theoretical consideration and empirical analysis of *human activity*. This increases understanding of individuals, co-operative practices within communities and the culture of the society. The incorporation of knowledge of human practices into the design presents an important challenge for HTI research.

Also the *design work* itself needs analysis and reconsideration. There is a need to understand the designer's ways of thinking and acting, and the constraints that (s)he faces in the actual design activity.

7.5.2 Continuous connection to users

Continuous user studies parallel to product development activities should maintain a clear understanding of the physical, social and technical environments which the new technology targets. In addition to designing individual products with the human-centred design approach, a wider view will also be needed. Users should be involved in determining how the possibilities brought about by new technologies could best be utilised in their lives. This requires a human-centred design approach also in the design of basic technologies and their components.

An often-forgotten user group is the *service and content providers as well as application developers*. These actors are the users of the new technologies and their aim is to offer meaningful services to consumers. They should be involved in the development of technology, taking into account from the very start how the technology will be utilised in real applications and services.

7.5.3 Involving all actors of the value network in the design

To reach the market, new products and services should be affordable to users and bring reasonable business to the organisations involved in the service chain. The business models and pricing models should be developed and assessed as an integral part of the design process. The multidisciplinary design approach requires experts in the human sciences, technology and business.

New services may generate new business models that will appear and exist alongside existing ones. All the actors in the value networks should participate in planning what kinds of future business and value networks new technologies will require or generate. It should also be studied what kind of values and attitudes the customers now have and how these may be evolving. An important future trend will be value networks based on the user's own content creation and management.

7.5.4 Coping with concurrent and distributed design environments

Human-centred design methods need to be developed so that they better support today's concurrent and distributed design processes. Stepwise feature introduction, where features are designed, implemented and evaluated one by one, is a promising approach.

Current usability design practices are targeted to the design processes of individual products. In the future, emphasis will be on service entities where several computers communicate together and with the user. The human-centred design approach should be applied to these entities in addition to individual products and systems. Human-centred methods that have been developed for the design of complex information and control systems provide important input to the synergetic development of a generic human-centred design methodology.

7.5.5 New technologies require new HTI research methods and offer new forms of collaboration

Ambient intelligence will fundamentally change the way people use computing devices to perform their tasks. The development of effective methods for testing and evaluating the usage scenarios enabled by ambient intelligence is an important research area. The dynamic nature of some of the usage situations, device heterogeneity, resource availability and the widely varying social environments where the applications and services are being used place numerous challenges on design and evaluation methods. Major challenges to contextual design are the varying contexts of use, as well as context awareness in services. Novel user-interface technologies will require new ways to illustrate and evaluate the solutions with users.

New technologies also provide new possibilities for design methods themselves. Virtual reality techniques can be used in illustrating and evaluating product concepts. Advanced process simulations will be important tools for design, evaluation, training and accumulating usage experiences.

HTI with emerging technologies and application areas should be studied as a whole, together with different actors in the field. In this way user needs for service entities can be identified more clearly, and usability challenges can be identified and solved sooner.

HTI research groups should be open to new researchers from various disciplines. The exploitation of industrial design has long traditions in the shaping of products for consumers. The skills and practices of industrial designers in giving tangible form to something that does not yet exist should be utilised more extensively also in the design process of industrial ICT solutions.

8. Summary and conclusions regarding the facilitation of HTI research at VTT

8.1 Summary

At the beginning of this report we defined human-technology interaction (HTI) as the functioning of a distributed collaborative system that the users and the technology form together with their physical and social environment. HTI research focuses on the ways technologies mediate the interactions in this system. The development of technologies takes place in a societal context, which creates possibilities but also puts constraints on the development.

In Chapters 4, 5, and 6 we elaborated the present most relevant drivers of HTI. The implementation of information technologies has vastly increased the availability of information and connections in people's everyday and working activities. As a consequence, the complexity of the interactions has increased. People face difficulties with information overflow, the diversity of different devices, applications and equipment as well as the continuous introduction of new applications and updates of existing ones. This has caused frustration and lack of confidence, resistance to the use of technology, or inefficient exploitation of existing possibilities. A great amount of secondary tasks have emerged which are time-consuming and draw much of the user's attention. This further tends to induce physical and mental load and even prevent the use of technology.

The creation of possibilities to embed technology in smart appliances and environments together with the development of multimodal interface technologies are expected to ease the use of the basic sensing, measurement, processing and transmission capacities of the information technology. However, the new ways of applying ICT have simultaneously deepened the demands on usability. Moreover, questions regarding safety and operability, security and personal privacy have gained new relevance.

The central aim of HTI research is to enhance the implementation of information technologies in solutions that are more functional, usable and meaningful for people. The research challenges in fulfilling this aim were identified in the Chapter 7 of our report. For better comprehension of the challenges we developed a systemic conception of HTI and depicted it in Figure 14. The systemic model made explicit the role of enabling technologies for all three interconnected interaction aspects of HTI. Moreover, it emphasised that the design of HTI should follow the principles of human-centred design. In Figure 15 the research challenges identified in chapter 7 are summarised with the help of the systemic HTI concept.

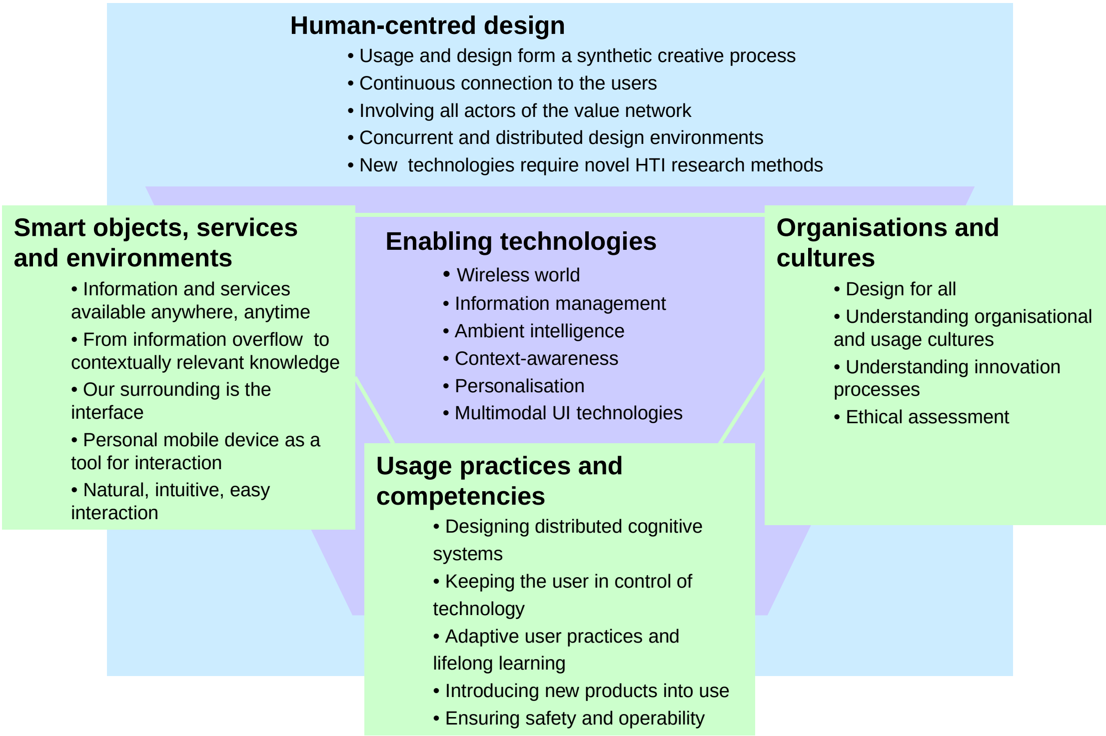

Figure 15. Systemic conception of HTI and HTI-research challenges.

8.2 Organising research in HTI issues

VTT is a multitechnical and multidisciplinary research institute with living connections to industry, business life, national authorities and institutions. Hence, VTT is in a strategic position to tackle the complex research challenges regarding HTI in the society, and to organise comprehensive and synthetic HTI research. By developing excellence in HTI issues, and by offering innovative approaches in the design of functional and meaningful technologies for future human practices, VTT could promote the competitiveness of Finnish enterprises. Mastering HTI issues is a central constraint on the quality of the products and services and, consequently, on the economical success of enterprises.

The creation of cultural, mental, physical and economical conditions for internationally recognised HTI research may be considered a strategic task for VTT today. The articulation of HTI as a key technology action topic within the VTT technology strategy has already taken place.

In Chapter 3 we reviewed the current HTI research in four VTT institutes. There is already a lot of research diverse research going on at VTT, at present around 70 projects. The strength of VTT include long traditions in field studies, close connection to technology development and industry, multidisciplinarity as well as good coverage of different HTI research fields. This forms a good basis for the future. However, there is an evident need to improve the coherence of the present efforts and to respond to the HTI research challenges in close cooperation with the industry. In the following, we outline our suggestions for the next steps in the strategic task of strengthening HTI research at VTT.

8.2.1 The goals of future HTI research

In this report, we adopted the principle that technology should be developed according to the needs and the meaningful practices of people. From taking this position it follows that the trajectory of HTI research must be envisioned in connection to the actual domains of practice and application areas of technology. Hence, the projection of the future development of HTI-research should be accomplished as an integral part of the roadmaps for specific application areas and domains of work or other human activity. The challenging task for the HTI-research community is to participate in the domain-oriented envisioning by identifying relevant research and development needs that contribute to human-centred technology development.

On the basis of the domain-specific research work, a further responsibility of the HTI investigators at VTT is to conceptualise generic issues and problems of human activity in the modern knowledge society. This is needed for enhancing theoretical understanding of human activity and for the development of adequate methods and tools for the development of the usage and design activities. A valuable tool in comprehending the generic features of human activity is the possibility to make inter-domain comparisons. The multitechnical and practice-oriented research activities of VTT provide ideal possibilities for interdomain comparisons and synergy. The HTI-research challenges that have been identified in this report represent our present comprehension of the generic research needs in the HTI area. The systemic conception of HTI and the research challenges depicted in figure 15 constitute a map of the HTI to be used in construction of domain-oriented roadmaps for human-centered technology development.

HTI research should aim at following goals:

- *Promoting innovations in technology.* Taking human activity as the starting point of development of artefacts facilitates early innovations by creating realistic demands and novel problems for technological development.

- *Promoting human-centred design.* Design and usage form an unbroken and continuous cycle. Users should be involved in the development of technologies from the concept design to the testing, evaluation and validation of the design. User participation should be considered even in the development of basic technologies. Research should be based on integration of theory and practice.
- *Facilitating the implementation of new products into use.* It is important that the development of solutions and products does not stop on the prototype level. The design process should involve all the actors of business chains that facilitate the delivery and maintenance of new products. An important part of the design is to plan how new products should be introduced to users and how to ensure that the users can effortlessly acquire, take into use and learn to use the new products.
- *Taking ethical issues into account in the design.* New information technology is increasingly becoming involved in people's everyday life. It should be ensured that technical solutions do not invade privacy or misuse people's trust in it. This often requires public discussion in the society. While design for all is a generally accepted value, concrete actions towards this goal are still needed. Lacking that, action may create an increasing digital divide in the society. The ethics of HTI research also aim at usable technology that increases efficiency, safety and wellbeing in work and everyday life.

8.2.2 The strategic instrument – HTI network of excellence

We suggest that some internal initiative is needed for conveying the message that HTI is part of the VTT technology strategy and that actions need to be taken to develop this area in the future. Consequently, we maintain that it is important to build up a *network of excellence* in the HTI area. It could be labelled *HTInet*. The *HTInet* should be made visible to the customers, and other interested parties by developing *HTIportal* that would offer an immediate access to the expertise that VTT provides in the HTI area.

The systemic HTI concept and the research challenges identified in this report define the *strategic aims* of HTInet for VTT. The network is our instrument for organising internal actions towards these aims and to open doors to national and international collaboration.

As a *strategic instrument, HTInet* emphasises knowledge sharing and effective organisation of collaborative empirical research and development in an open environment, within which a new interdisciplinary and interdomain culture may emerge. *HTInet* must not compete with the VTT themes or existing portals. Instead, it should grasp at ideas and problems identified within these contexts, articulate them into HTI-relevant research questions and refine them into innovative problems to be scrutinised in practical analysis, and through experimentation and evaluation.

Further, it is proposed that VTT should internally share HTI knowledge by organising workshops and seminars. *HTInet* should also promote HTI issues in the preparation of new research projects, particularly in questions and areas where the HTI point of view has no traditions. VTT should also enable financial prerequisites to develop the strategic content of the network and promote its regular knowledge sharing activities.

HTInet enables experimentation with new information technology possibilities in practical contexts. This could be fascinating for doctoral students and young research scientists. The HTI topic also offers challenging questions for deep theoretical scrutiny. *HTInet* should have resources to support young scientists' interaction with international HTI research centres; the network should have resources to invite guest speakers and researchers for joint workshops and for more extensive collaborative work; and it could take the initiative for preparing proposals for international research programmes.

HTInet requires *resources for knowledge sharing and diffusion*. One person should be made responsible for the coordination of network activities and a core group should support this task.

8.2.3 Two interdomain objectives for HTInet

HTInet should in the immediate future prepare research on two focal areas that facilitate the crossing of boundaries between the consumer and professional domains and that are relevant for many application areas and activity domains. We believe that VTT has potential for boundary crossing and, hence, is in a position to achieve synergy and new innovative solutions. HTInet should first focus on the following research topics:

1) Design of natural interaction with smart environments

This research topic focuses on enhancing people's abilities to deal with technology and the artefactual environment for improving their adaptive control over technology.

The topic deals with designing meaningful representations of complex and invisible phenomena, enabling timely, adequate and effortless operating of smart objects and services and interpreting the results of operations, orienting and making sense of large amounts of information. The question of natural, or intuitive, technology and interfaces is a theoretically challenging research topic.

Tackling this topic assumes theoretical conceptions of human perception and action. Traditional views appear inefficient, and paradigmatic changes in understanding cognitive systems are called for. It is important to understand interaction with different modalities in the comprehension of the environment and the role of action in making sense of the environment. Furthermore, more insight is needed to understand the role of conceptual mastery in immediate perception, and the ways of embedding theoretical understanding into natural interfaces. New methods for the analysis of users' perception, operations and skills in context are needed and design principles for ecological i.e. natural design should be formulated. An important issue is how to consider safety and operability problems in natural interface design.

2) Innovations in implementation of smart technologies

This topic focuses on finding ways to improve the implementation of technology into practice. It is claimed that genuine new technical and social innovations are needed to improve the efficiency of change processes and their results.

It has been argued that the development of information society is constrained by human and social factors. Solving the problems of taking smart technology into actual use is both a practical and a theoretical challenge that calls for real collaboration between technology developers and social scientists. Comparative analyses of user acceptance in industrial modernisation processes in organisations, and in adopting everyday appliances into use, are expected to be especially informative. They could reveal the underlying cultural determinants and social dynamics of the ongoing rapid change in the artefactual environment.

The topic calls for reconsidering the notions of usage and design and for understanding how to establish spatial and temporal continuity of the technological development. The role of implementation should be studied empirically. Likewise, empirical studies of the dynamic decision-making in design and coping with the uncertainties of the design process should be facilitated, and comprehension of the core-task demands of design should accomplished. Methods for collaborative design should be tested, as well as valid methods for the analysis of usage to be used for the design purposes created. Follow-up studies of the use of the new technologies accomplished and new insight of innovation chains should be created.

Both research topics realise the ambient intelligence vision. This vision poses challenges in the following areas: Post-WIMP interaction technologies, smart technologies for awareness, and support for mobility and services to be adaptive for use wherever and whenever. HTI research also exploits the new ICT solutions within the domain of control and information systems, in which innovations are needed for better integration of information, enhanced mobility in the access of this information, new simulation methods and virtual reality techniques. New innovations are required for presentation of relevant information with the aim of increasing the natural ecology of the artefactual environment and for visualising the invisible in complex systems.

The above two topics form integrative themes that cover many research challenges identified in this report. The topics require investigations with regard to the interface, task and socio-organisational aspects of HTI. The problems should be studied in real user contexts and/or in the context of actual design and development of new artefacts. One of the most challenging tasks is to identify such practical problems of design and usage that both enable and require scientific elaboration and analysis. Identification of these problems should be accomplished in interaction with enterprises and industries that have business interests with regard to improving the human-technology interaction of their products and services.

8.2.4 HTInet promotes human-centred development of technology at VTT

HTInet promotes human-centred development of technology at VTT. It is our conviction that a larger and larger part of the technical research and development at VTT should adopt this mission. In order to create knowledge that is needed to materialise the value of the human-centred development of technology, new ways of carrying out research and development should be adopted. Following principles elaborate the internal *way of working* within HTInet. These principles emerged from our analysis of the nature of HTI issues. The principles also cohere with formulations that have currently been identified as central in international discussions regarding the organisation of HTI research (Jutand 2003).

- *Improved disciplinary focus in research projects:* In a research domain that unquestionably requires interaction between research and product development, there is always a tendency to reduce research to consulting. Research scientists may become a reservoir of resources for the customer, who is coping with the demands of a fast-paced development project. Such an orientation in research is too short-sighted. Making innovations implies some risk. The development of sufficient expertise for reaching the forefront of the domain and achieving genuine results requires not only time and resources but also a research community with traditions.

- *Interdisciplinary work in the projects.* The HTI projects should by definition be interdisciplinary. This principle is, however, not simple to realise. There are differences within the engineering disciplines and also between engineering and natural sciences that may impede communication. Undoubtedly, the most challenging demands on interdisciplinary work arise when natural science and engineering meet with behavioural sciences. The articulation of common goals and concepts requires insight of the need for this collaboration, appreciation of the value of the other partners' point of view, and the availability of resources for dialogue. A new research culture should emerge.

- *Integrate theory and practice.* As human action is contextually determined it is necessary to comprehend the tasks and artefacts from a context-specific perspective. Context-specificity is a resource that brings synergy via collaboration across domains of application. The notion of human-centeredness should, further, be understood as a profound principle that refers to the way of conceiving knowledge and its construction. Knowledge that emerges in the skilled work of people is equally valuable to that created in scientific work. Respecting the epistemic value of both types of knowledge creates a fruitful dialogue between people from the research facilities and those from the practice. The latter may be designers, production engineers or operators and end-users.

- *Combine field and laboratory.* An extremely complex object that embraces not only the phenomena of the physical world, but also those of human action, cannot be treated with deterministic or very reduced research approaches. A research methodology should be created that comprehends the ontological diversity of HTI and includes tools for studies in the laboratory, in virtual reality and simulations and in field conditions. Not only controlled measurements of different subject matters but also people's conceptions should be considered. Our aim is to extend the involvement of users and make the interaction between the design laboratory and the field continuous. This is needed to acquire realistic feedback of the usage of technologies and for collecting experiences for further innovations.

- *Real prospective studies.* The level of aspiration in HTI research should be high. It is not sufficient to make improvements in the current technologies; there has to be a willingness to innovate and experiment with new possibilities. These may be created when the demands of users and the enabling technologies meet. The users should be involved in the design as innovators of new ways of exploiting the emerging technological possibilities.

- *Work with industrial designers and other creative professionals.* It is important to include a creative point of view in HTI research. Creative professionals not only take care of the aesthetic features and style of presentation of new products; more profoundly, they can perceive without conventions the new perspectives of the human being and the possibilities the environment affords. Creative professionals convey meanings, the relationships that make the world, and our activities that are significant for us.

The work within HTInet is based on shared awareness of the significance of HTI issues for the future development of technology. The participants in *HTInet* share the insight that the development of HTI necessarily requires new practices of the kind described above. *HTInet* supports the construction of such practices and research culture. The transfer of HTI knowledge to stakeholders and industries will probably attract these partners to participate in the network activities and, also, to finance well-focused research projects.

8.3 Final remarks

It has been the aim of this report to analyse human-technology interaction as an important issue in the development of knowledge society technologies. We have pointed out significant areas for HTI research and given reasons for focusing on innovative scientifically-demanding research questions that have value for the development of human practices. By adopting this strategy, VTT could contribute to the success of Finnish enterprises in the global market, within which human-centred design has been identified as a key success factor.

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Human-Technology Interaction Research and Design VTT Roadmap

Executive summary

Leena Norros, Eija Kaasinen, Johan Plomp & Pirkko Rämä

Human-technology interaction (HTI) research focuses on the ways in which technologies mediate the interaction between the human actor and his/her environment. In recent years, human-technology interaction has been shaped by the rapidly developing information and communication technology (ICT) and its applications in new types of user interface. New forms of HTI are implemented in all spheres of modern society, in *everyday life*, in *systems of production* and in *institutions and culture*. The central aim of HTI research is to improve the implementation of information technologies in solutions that are more functional, usable and meaningful for people. Because the quality of HTI greatly affects the overall acceptability of new technologies, HTI issues play a significant role in the *economical competitiveness and successfulness* of products and services.

VTT is a multitechnical and multidisciplinary research institute with living connections to industry, business life, national authorities and institutions. Hence, VTT is in a strategic position to tackle the complex research challenges regarding HTI in modern society, and to organise comprehensive and synthetic HTI research. The creation of cultural, mental, physical and economical conditions for internationally recognised HTI research may be considered a strategic task for VTT today. The articulation of HTI as a Key Technology Action within the VTT technology strategy has already taken place. The following issues are considered essential in the strategic positioning of HTI in the VTT technology strategy.

Proactive human-centred perspective of technology development

HTI is not an isolated issue of design but a *perspective of technological innovation and development*. HTI brings forth the idea that changes in technology impose changes in human practices, and that we should not aim at replacing human actors by technology but at improving and developing activity systems. In the past, the relevance of HTI issues has mainly been identified in a reactive way. Usability problems, human error, difficulties in the implementation of new everyday appliances or resistance to modernising production are well known. The great challenge of today is to adopt a *proactive approach in HTI design.* By this we mean that human performance and needs should be placed at the forefront when projecting the future development of technology. The consumer sector has been in the vanguard in implementing new design thinking. In the future, a much more comprehensive application of human-centred design will offer knowledge-intensive development possibilities in the industrial and public sectors. Economical savings for the society, and improvements in safety and in the wellbeing of people could be expected from the proactive consideration of HTI issues.

Deeper understanding of human behaviour is needed

Taking into account the users' needs in design and involving users in the design process have become established *values* in design, and guidelines for human-centred design have been produced by international organisations. However, future forms of usage and the needs of users are very difficult to predict and tackle in the actual practices of design. Theoretical and conceptual *understanding* of the nature of human performance, methods to construct such knowledge in different contexts of use, and ways of implementing them in the design process are required.

Hence, on behalf of VTT we have looked closely at the international development of HTI research and reflected on the state of the art of HTI research at VTT. The situation at VTT was viewed with the help of the descriptive model depicted in Figure 1. The model demonstrates the notion of tool-mediated human-environment interaction and elaborates the diversity of research topics that may be connected to HTI. The descriptions regarding HTI activities at VTT Building and Transport, VTT Electronics, VTT Industrial Systems and VTT Information Technology were compared with the help of the above model. We found that about 70 research projects could be linked to the HTI theme. The content and nature of these correspond to the research traditions and application domains of their hosting units.

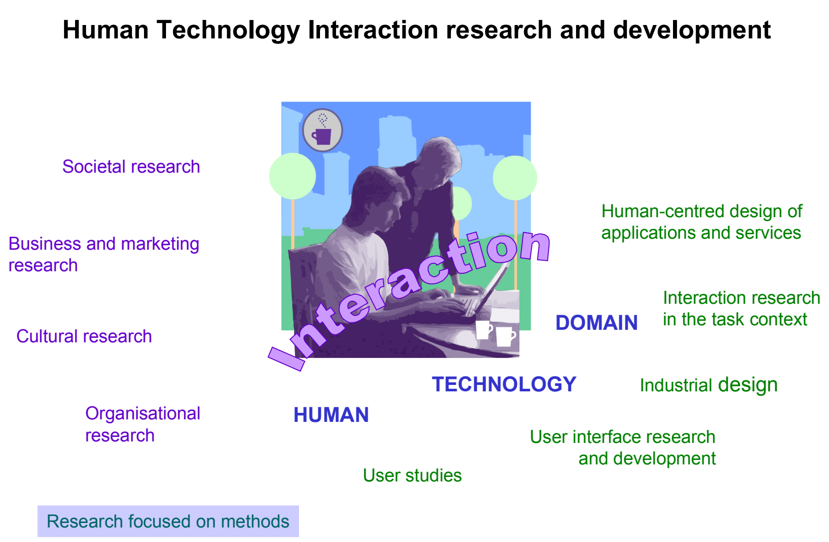

Figure 1. Different focuses of HTI research.

As a result of our review the concept of HTI was developed further. Interaction should be analysed on different systemic levels, as situationally constrained operations, goal directed actions, and as societally defined activities of organisations. The artefacts enable the shaping of the environment and the possibility to control one's own actions.

A HTI concept was developed that consists of three *interaction perspectives* that reflect the systemic levels of HTI. The perspectives are *Smart objects, services and environments, Usage practices and competencies, and Culture and organisations*. These are depicted in Figure 2.

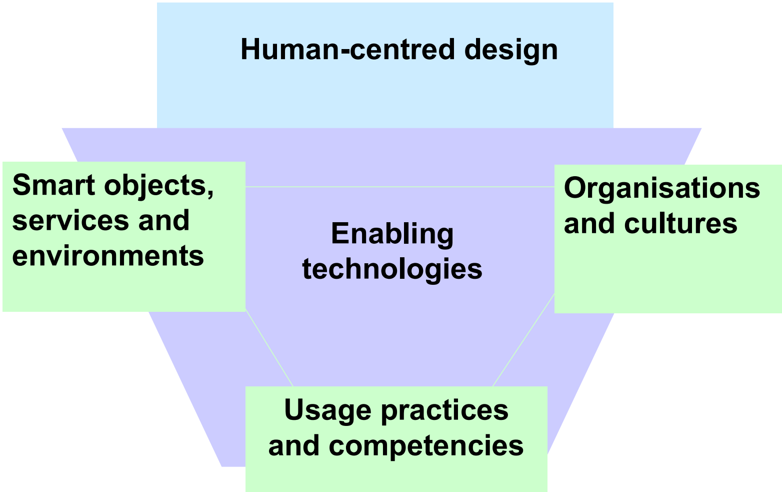

Figure 2. The HTI research domain.

Information and communication technology intensifies the demands on HTI

ICT has developed into a generic form of technology in the knowledge society. In recent years many technology roadmaps have been produced to forecast the future development of information technologies. It has become evident that ICT will have profound impacts on all spheres of life. *Enabling technologies* are key technologies that will be needed for new HTI concepts and that will markedly shape human-technology interaction in the future. Enabling technologies are relevant with regard to all three aspects of HTI. The central role of enabling technologies is indicated in the HTI research domain model (Figure 2).

The development of information technology reshapes people's ways of interacting with the environment. It also changes the environment itself as technology becomes embedded in it. New forms of distributing intelligence in the cognitive structures of interaction and new ways of cooperation emerge. The enabling technologies not only change our practices; they also question our learned conceptions regarding human cognition. In analogy to the functioning of a computer, human cognition has been conceived in terms of linear information processing. Recently, this metaphor has lost its explanatory strength. As optional cognitive theories have advocated, cognition is not located in the human brain only. Rather, it is conceived as a social phenomenon that is distributed between the brain, the human physical body, the social structures of activity, the artefacts and the environment. The enabling technologies make the predictions of the theory visible.

The embedding of technology in the tools and the environment on the one hand, and the economical pressure for fast development cycles in design on the other, is fuelling the drive for a reorientation in design. The whole lifecycle of the products has to be taken into account, and the future contexts of use and the needs of the users should be anticipated as early as possible in the design process. Both demands increase the need for improving the *human-centred design (HCD)* approaches. One of the challenges of HCD is the integration of all three aspects of HTI in the design process.

Technology must be developed in context-informed ways

We are used to thinking that the formulation of generic laws and rules is the ultimate aim of scientific work and rigorous thinking. Recent developments in both natural and social sciences have, however, brought up the notion of the context-dependence of knowledge, action and the usability of technologies. The usefulness of knowledge in practice has been considered an important truth criterion of knowledge, and the adaptiveness of artefacts to the contexts of use provides great challenges for today's design.

From these premises it follows that the projection of future artefacts requires that the domains of usage be known. This is where VTT is at a significant advantage thanks to its multitechnical and application-oriented tradition. There are innumerable usage contexts and many broader domains of application of technologies. The different units of VTT reflect one conceptualisation of the domains and the VTT technology themes a further complementary decomposition. These domains, and new ones that typically emerge in the boundary areas of the old, are potential targets of intensive HTI research.

The group did not aim at providing domain-specific roadmaps. Neither was it considered relevant to project context-independent research challenges of HTI on a timeline. Instead we chose, first, to analyse the generic societal and technical changes that appear to increase the need for understanding of HTI issues, and, second, to identify research challenges of the future.

Societal, technical and design drivers for HTI

Drawing on current literature and our own research we identified generic tendencies and pressures for change in the modern information society. The societal drivers were considered first. The traditional ‘technology push’ view was found inadequate as it does not sufficiently focus on the needs of people in the information society. *Users should be considered as active innovators who make technology meaningful* in their everyday life. Creating meaningful usage has become an important factor for the economical success of technological innovations. In attempting to take into account the users’ point of view it is necessary to consider the changes in the general attitudes towards work, and to scrutinise the new cultures that emerge as the temporal, spatial and organisational constraints of work and everyday life change.

As information technology products are increasingly targeted to the general public, it becomes essential that the *needs of all user groups* be taken into account in design. Further societal issues that were identified concerned the development of *new economy* and the emergence of *network organisations*. It was also stated that people face an increasing pressure of *learning*. Creation of *flexible* competencies in work and everyday life is necessary. Life is qualified by the increase of information and the complexity of phenomena that should be comprehended.

In the identification of technical drivers a dozen recently produced technology roadmaps were reviewed. The most relevant topics with regard to HTI were identified and tackled in some detail. The most influential HTI-relevant technical drivers are the availability of *wireless technology* and increasing *mobility*, the availability of *immense amounts of information* and the efficiency of its transmission and copying, and the *ambient intelligence* and *new types of user interfaces* that reshape people’s relationships with the environment.

We also studied the pressures that affect current design practices and methods. Technological possibilities and economical pressures create a demand for *fast, complex and concurrent design processes*. The management of this demand requires new knowledge and expertise regarding *comprehensive design processes*. Human-centred design needs to take *a wider view* from individual applications and services to infrastructures beyond the applications. Human-centred design is becoming the major paradigm of design but *methods* for its realisation need further development. Introduction of new products and *implementation of technologies* is a major bottleneck in the development of the knowledge society. Possible risks in the implementation of new technologies should be considered, as *safety and operability and environmental issues* are important values and targets for the lifecycle management of products and services.

HTI challenges

The challenges for HTI research were inferred on the basis of the analysis of social, technical and design drivers. In the report we elaborate the connections of the challenges to the identified drivers and describe the content of the challenges. The most important research questions are also mentioned.

The challenges were studied and classified according to the model of the HTI research domain (Figure2). Figure 3 depicts the result of our analysis.

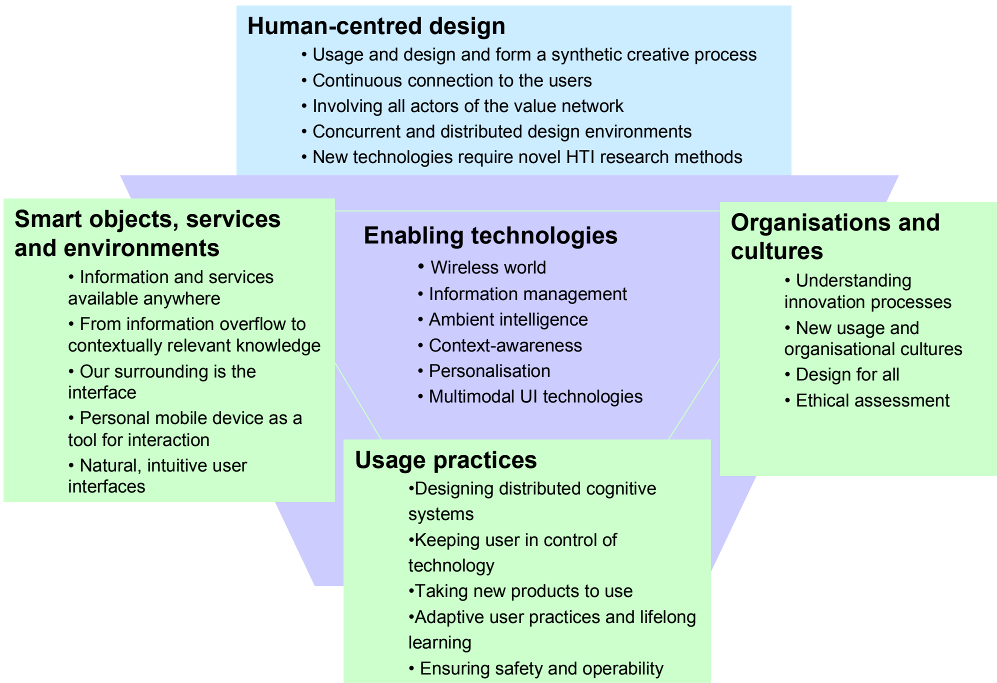

Figure 3. HTI research challenges.

We identified 25 challenges that were considered most significant for the future development of HTI and ICT. Each challenge identified in the analysis deserves intensive research and development.

- The design of smart objects, services and environments creates challenges that deal with creating more *intuitive and natural ways of interacting* with the artefacts and the artefactual environment. The usability of new devices is dependent on the development of the *perceptual and operative habits* of the user. Improving the *presentation of information* of complex connections and invisible phenomena, and making large amounts of *data manageable* require new innovations.

- The understanding of usage practices and competencies includes challenges that address the problems of creating *distributed intelligence* that is shared *between the tools, the human actors and the new smart environment.* It also tackles the questions of creating *meaningful tasks*, improving *situated decision-making* and developing new *competencies* and practices. Safety and operability issues also need consideration and development of *core-task informed user practices.*

- Management of organisations and culture denotes challenges that include understanding of *usage* and *organisational practices* from the *cultural point of view.* Culture should be seen as an important determinant of a safe, appropriate and meaningful application of technology. Usage and organisational cultures shape the *implementation* and the development of technology and should be understood better. *Ethical issues* of the development of technology should also be tackled, as well as the problems of *innovation processes*. These issues view HTI and the development of technology in a wider societal perspective.

HTI issues appear in practice as multifaceted problems. The systemic HTI model conceptualises the problems and makes explicit the connections between phenomena. Research projects and programmes should be launched in which practical real-life problems can be studied from different HTI perspectives but in connection to each other. A holistic understanding of HTI is needed for innovations and for appropriate design. In the HTI context the enabling technologies are studied and developed in connection to the above-mentioned problem areas and approached from the human-centred design perspective.

Comparative inter-domain research topics for VTT's HTI research

The identified challenges offer many important research topics that must be concretised according to the specific needs of the application domains. At the same time, inter-domain studies are required to enhance the understanding of the nature of HTI phenomena through comparison and benchmarking. Comparative studies facilitate the development of methods of HTI research, and the comprehension of the human-centred design, and provide information on the usefulness of enabling technologies. Two main topics were identified as focal areas of inter-domain HTI research. These are:

1) Developing new concepts for natural interaction with smart environments

This topic focuses on enhancing people's abilities to manage with the new tools and artefactual environment, and to improve their control over technology. The topic concerns the *product aspect of HTI.*

2) Innovations in implementation of smart technologies

This topic focuses on finding ways to improve the implementation of technology in practice. It is claimed that genuine new technical and social innovations are needed to improve the efficiency of change processes and their results. This topic relates to the *design aspect of HTI*.

Solving the problems of taking smart technology into actual use is both a practical and a theoretical challenge that calls for collaboration between technology developers and social scientists. Comparative analyses of user acceptance in industrial modernisation processes in organisations, and in adopting everyday appliances into use, are expected to be especially informative. They could reveal the underlying cultural determinants and social dynamics of the ongoing rapid change in the artefactual environment.

The strategic instrument – HTInet & HTIportal

HTI is part of the VTT technology strategy. Hence, actions are needed to develop this area in the future. It is proposed that VTT could establish a *network of excellence* in the HTI area. This could be called *HTInet*, and it should be made visible to customers and other interested parties by developing the *HTIportal*, which would offer immediate access to the expertise that VTT provides in the HTI area. The systemic HTI concept and the research challenges identified in this report define the *strategic aims* of *HTInet* for VTT.

HTInet emphasises knowledge sharing and effective organisation of collaborative empirical research. *HTInet* must not compete with the VTT themes or existing portals. Instead, it should grasp at ideas and problems identified within these contexts, articulate them into HTI-relevant research questions and refine them into innovative problems to be scrutinised in practical analysis, and through experimentation and evaluation.

HTInet promotes human-centred development of technology at VTT

An increasing proportion of the technical research and development at VTT should adopt this mission. Its realisation requires new research and development practices. The following principles elaborate the internal *way of working* within HTInet.

Improved disciplinary focus in research projects: In a research domain that requires interaction between research and product development, there is a tendency to reduce research to consulting. Such an orientation is, however, too short-sighted. The development of sufficient expertise to reach the forefront of the domain and achieve genuine results requires not only time and resources but also a research community with scientific traditions.

Interdisciplinary work in the projects. The most challenging demands on interdisciplinary work arise when natural science and engineering meet with behavioural sciences. The articulation of common goals and concepts, appreciation of the value of the other partners' point of view, and the availability of resources for dialogue, denotes the emergence of a new research culture.

Integrate theory and practice. As human action is contextually determined, it is necessary to comprehend the tasks and artefacts from a context-specific perspective. Context-specificity is a resource that brings synergy via collaboration across domains of application.

Combine field and laboratory. HTI is an extremely complex object that embraces not only the phenomena of the physical world, but also those of human mind and action. A research methodology should be created that comprehends the ontological diversity of HTI and includes tools for studies in the laboratory, in virtual reality and simulations and in field conditions.

Real prospective studies. The level of aspiration in HTI research should be high. It is not sufficient to make improvements in the current technologies; there has to be a willingness to innovate and experiment with new possibilities. The users should be involved in the design as innovators of new ways of exploiting the emerging technological possibilities.

Work with industrial designers and other creative professionals. It is important to include a creative point of view in HTI research. Creative professionals not only take care of the aesthetic features and style of presentation of new products; more profoundly, they can perceive without conventions the new perspectives of the human being and the possibilities the environment affords.

Final remarks

We have pointed out significant areas for HTI research and given reasons for adopting an innovative scientifically demanding research approach. By adopting this strategy, VTT could contribute to the success of Finnish enterprises on the global market, within which human-centred design has been identified as a key success factor.

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Human-Technology Interaction Research and Design
VTT Roadmap

Abstract

Human-Technology Interaction is a human-centred perspective to technological innovation and development that has great relevance to the economical success of technical products and services. The aim of HTI research is to enhance the implementation of information technologies in solutions that are more functional, usable and meaningful for people. This report defines the central issues of HTI research. It provides an overview of the history of HTI research and elaborates on the different traditions within it, and the state of the art at VTT is briefly sketched.

The societal and technical drivers of HTI were surveyed to enhance understanding of the factors that effect the developments in this field. The implementation of information technologies has vastly increased the availability of information and connections in people's everyday and working activities. As a consequence, the complexity of the interactions has increased. People face difficulties with information overflow, the diversity of different devices, applications and equipment as well as with the continuous introduction of new applications and updates of existing ones. The creation of possibilities to embed technology in smart appliances and environments together with the development of multimodal interface technologies are expected to ease the use of the capacities of the information technology. However, the new ways of applying ICT have simultaneously deepened the demands on usability. Moreover, questions regarding safety and operability, security and personal privacy have gained new relevance. As consequence the implementation of technologies in use create major challenges and need for research and innovations.

Integrating the possibilities that the enabling technologies provide and the demands of the users creates a great number of research challenges. For better comprehension of the challenges we developed a systemic conception of HTI. This model makes explicit the role of enabling technologies for all three interconnected interaction aspects of HTI, "smart objects, services and environments", "usage practices", and "organisations and cultures". Another aspect of HTI is the human-centred design methodology, which needs to be further developed. All together 25 hot topics were identified as challenges for research. Their interconnections are made explicit with the help of the systemic HTI concept. In the final part of this document recommendations are made for the direction of HTI research at VTT.

Keywords
user-centered design, human-machine interface, smart human environments, cognitive ergonomics, enabling technologies, knowledge society, usability

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VTT's technology strategy defines focus areas of strategic research. One of the areas is Human-Technology Interaction (HTI). HTI research focuses on the ways in which technologies mediate the interaction between the human actor and his/her environment. HTI has been shaped by the rapidly developing information and communication technology and its applications in new types of user interfaces.

HTI is not an isolated issue of design but a perspective of technological innovation and development. HTI brings forth the idea that changes in technology impose changes in human practices. We should not aim at replacing human actors by technology but at improving and developing activity systems. HTI research supports functional, usable and meaningful implementation of information technologies.

This report provides an analysis of the generic societal and technical changes that increase the need for understanding HTI issues, and it identifies research challenges in the following areas: Enabling technologies, Human-centred design, Smart objects, services and environments, Usage practices and competencies, and Culture and organisations.

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