Contract Number 034051

InterLink

International Cooperation Activities in Future and Emerging ICTs

Coordination Action
Priority 2 Information Society Technologies

Deliverable number D4.2
Road-Mapping Research in
Ambient Computing and Communication Environments

Towards The Human City:
White Paper on a Future Research Agenda

Due date of deliverable: Month 27
Actual submission date: 1 December 2009

Start date of project: 1 October 2006 Duration: 32 months

FhG Version 2

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(Based on input from the participants of the different InterLink Workshops)

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	**PU**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
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Executive Summary

Points of Departure: The evolution towards a future information and knowledge society is characterized by the development of personalized individual as well as collective services that exploit new qualities of infrastructures and components situated in smart environments. They are based on a range of ubiquitous and pervasive communication networks providing ambient computing and communication at multiple levels. The services are provided by a very large number of "invisible" small computing components embedded into our environment. They will interact with and being used by multiple users and supported by an "infrastructure" of intelligent sensors and actuators embedded in our homes, offices, hospitals, public spaces, leisure environments. New and innovative interaction techniques are being provided that integrate tangible and mixed reality interaction providing a more holistic and intuitive usage and interaction experience than today. Economics will drive this technology to evolve from a large variety of specialized components to a small number of universal, extremely small and low-cost components that can be embedded in a variety of materials. Thus, we will be provided with a computing, communication, sensing and interaction "substrate" for systems and services. We can characterize them as "smart ecosystems" in order to emphasize the seamless integration of the components, their smooth interaction, the "equilibrium" achieved through this interaction and the "emergent smartness" of the overall environment.

Part 1: While the area of Ambient Computing and Communication Environments evidently faces a large number of issues and challenges, the report highlights in its first part especially two grand themes as being of major relevance: "Socially Aware Ambient Intelligence" and "Privacy, Trust, and Identity". Applications and services will behave in a "socially aware" way. They will provide a sense of involvement and knowledge about the social behavior of other persons, such as their degree of attention, desire for customization and control, their emotional state, interests as well as their desire to engage in social interactions. The provision of smart service requires extensive data collection and analysis of personal private data. Socially aware services imply also an increase in voluntarily sharing of personal and intimate data for friends and peer groups. Both aspects call for Privacy Enhancing Technologies (PETs) and making them an integral part of system design addressing the conflict of ubiquitous and unobtrusive data collection/provision with human control and attention.

Part 2: In order to develop a roadmap for future research agendas, the theme of Urban Life Management in Smart Cities was selected as an umbrella scenario and as the starting point for the second part of this report. Based on this, the concept of "The Humane City" was developed as our vision for the City of the Future and the future of Urban Living. There are many arguments for the relevance of this umbrella scenario. The most important one is that already by the end of 2008, half of the world population lived in urban areas. People speak of an Urban Age that we have entered and predict that the economic prosperity and quality of life will largely depend on the abilities of cities to reach their full potential.

We can observe a development from real cities via virtual/digital cities to Hybrid Cities and then transforming them into Smart Cities. Obviously, there are many ways of addressing the challenges and issues of Hybrid and Smart Cities. One way to orient ourselves is to ask "what kind of city do we want to have? A technology-driven and technology-dominated one? Probably not. So, we developed the vision of a city where people enjoy everyday life and work, have multiple opportunities to exploit their human potential and lead a creative life. We call it "The Humane City".

Recommended Research Agenda: In order to contribute to overcoming the gap between today's situation and the vision of the future as expressed in the goal "Towards the Humane City: Designing Future Urban Interaction and Communication Environments", twelve research lines were developed. We recommend to use them as constituents of future research agendas in the area of Ambient Computing and Communication Environments. Their headings are:

R1: Rationale for Humane/All-inclusive Cities (users are citizens)

R2: Tangible Interaction and Implicit vs. Explicit Interaction

R3: Hybrid Symmetric Interaction between Real and (multiple) Virtual worlds

R4: Space-Time Dispersed Interfaces

R5: Crowd and Swarm Based Interaction

R6: Spatial and Embodied Smartness (distributed cognitive systems, outside-in robot)

R7: Awareness and Feedback (sensors, physiological, environmental …)

R8: Emotion Processing (affective computing)

R9: Social Networks and Collective Intelligence

R10: Self-Organization in Socially Aware Ambient Systems

R11: Realization and User Experience of Privacy and Trust

R12: Scaling (as the major horizontal issue)

Of course, we are fully aware that doing research along these lines will not automatically lead to Humane Cities and solve the problems of world population. The expected results have to be considered as contributions which interdisciplinary research in the area of Ambient Intelligence can provide towards the overall goals associated with the vision of Humane Cities.

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1 Introduction - Motivations

The Working Group 2 “Ambient Computing and Communication Environments” of the InterLink project ((http://interlink.ics.forth.gr) is concerned with identifying deficits, new challenges and developing a research agenda for future work as well as facilitating international collaboration in the thematic area briefly characterized as follows and elaborated later in this document.

1.1 Point of Departure

The evolution towards a future information and knowledge society is characterized by the development of personalized individual as well as collective services that exploit new qualities of infrastructures and components situated in smart environments. They are based on a range of ubiquitous and pervasive communication networks providing ambient computing and communication at multiple levels. The collective services are provided by a very large number of "invisible" small computing components embedded into our environment. They will interact with and being used by multiple users in a wide range of dynamically changing situations. In addition, this heterogeneous collection of devices will be supported by an “infrastructure” of intelligent sensors (and actuators) embedded in our homes, offices, hospitals, public spaces, leisure environments providing the raw data (and active responses) needed for a wide range of smart services. Furthermore, new and innovative interaction techniques are being provided that integrate tangible and mixed reality interaction. In this way, the usage and interaction experience of users will be more holistic and intuitive than today. It is anticipated that economics will drive this technology to evolve from a large variety of specialised components to a small number of universal, extremely small and low-cost components that can be embedded in a variety of materials. Thus, we will be provided with a computing, communication, sensing and interaction substrate for systems and services. We can characterize them as "smart ecosystems" in order to emphasize the seamless integration of the components, their smooth interaction, the "equilibrium" achieved through this interaction and the "emergent smartness" of the overall environment.
This area of research has close relationships to areas known as ubiquitous, pervasive or proactive computing, disappearing computer or ambient intelligence. We will therefore also use these terms in this text wherever appropriate, especially Ambient Intelligence (AmI). We adopt its characterization by the ERCIM Working Group SESAMI: “Ambient Intelligence represents a vision of the (not too far) future where "intelligent" or "smart" environments and systems react in an attentive, adaptive, and active (sometimes proactive) way to the presence and activities of humans and objects in order to provide intelligent/smart services to the inhabitants of these environments. While a wide variety of different technologies is involved, the goal of Ambient Intelligence is to hide their presence from users, by providing implicit, unobtrusive interaction paradigms. People and their social situations are at the centre of the design considerations.”

1.2 Goal, Evolution and Organization of this Document

The goal of this document is to identify current deficits and problems, to describe the resulting challenges and to develop a research agenda that will address the problems and help to develop appropriate solutions. The anticipated research agenda will serve as input for different types of organizations funding research at the national and the international level. One important target group of this report is the European Commission in the context of the preparation of its Framework Programmes, especially for the calls of FP8. The work was organized by bringing together international experts to "by-invitation-only" workshops which facilitated intensive small group discussions in different formats and subsequent elaboration of the results. Participants were selected in such a way that they cover an appropriate spectrum of approaches and backgrounds. Furthermore, the groups' composition was changed over time in order to bring in different people with new ideas. At the same time, there was an overlap of participants between the groups of the different workshops in order to assure continuity of the work (for a list of the participants of the four workshops that were held see the Appendix at the end of this document).

The first important step of the whole endeavour was the preparation of an extensive "State-of-the-Art" Report (STAR) which grew out of the discussions in the first two workshops held in May 2007 in Eze, France and in November 2007 in Eltville, Germany. As a result of these workshops it was agreed by the invited international experts that especially the following two areas needed special attention:

- The concept of *socially aware ambient intelligence* and means for its realization
- The conflict of data provision vs. control and human attention involving the resulting *issues of privacy, trust, and identity*

The final version of the STAR was prepared in January 2008 and is available for download at the InterLink website in the area of this Working Group 2. Section 2.1 of this document provides a summary of the main results of the STAR.

In June 2008, a third workshop was held at Keio University in Tokyo, Japan. For this purpose, a first version of the "white paper" was prepared by the Working Group leaders, distributed to the participants in advance and discussed at the workshop. This paper was building on the STAR but at the same time working towards the development of a research agenda. Its main new perspective was to provide an "umbrella scenario" guiding the research efforts and providing motivation and relevance for researchers as well as funding organizations. The umbrella scenario is "Urban Life Management" addressing the pressing issues of how to manage a person's / a group's life in today's and future cities and on how to manage the urban environment of today's and future cities. Some key facts about the growth of world population, in particular of cities, and its implications for our future prosperity and well-being, addressing environmental and social perspectives as well served as an additional motivation. Please note: The basic assumption is not that future information and communication technology based on ubiquitous computing and ambient intelligence will solve all our problems in the world but that it can help contributing to dealing with many key aspects of urban life management and to solve a number of important problems. The concept of "Hybrid Cities" was introduced and served as a starting point for identifying key dimensions of the research agenda.

The second version of the "white paper" presented again the concept of "Hybrid Cities" and its elaboration towards the "Humane City" (see section 2.2) and was discussed at the fourth InterLink workshop in Cannes in November 2008. The attendees of this workshop participated then in the road mapping process and identified 12 Research Lines. In the months after the Cannes workshop, they were elaborated by different contributors and are now presented in Chapter 3. The inclusion of the detailed research lines in this paper constituted the third and a further elaboration the fourth version of this white paper.

Finally, we described thematic relationships to the other two InterLink Working Groups and indicate opportunities for cross-thematic synergies. In the appendix, we listed the participants and organizers of all four workshops that were held.

2 New Issues & Challenges - Vision

On the basis of the "State-of- the-Art" report, we identified deficits and provided conclusions for future research efforts especially in the two areas reflected in the first two workshops (see also section 1.2). Deficits and challenges were especially identified for the extension of "traditional" ambient and ubiquitous computing environments, i.e., the need of moving from one-person and multiple devices to multiple-people and multiple devices in multiple contexts, either social or physical (locations/spaces). This can be illustrated by the following triangle relationship:

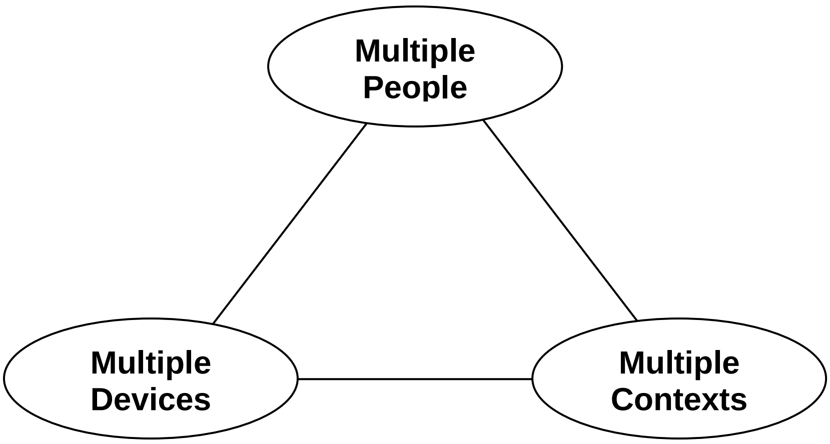


Figure 1 Triangle of Multiple People, Multiple Contexts, and Multiple Devices

2.1 Evolution of the area - emerging issues, challenges and expected impact

The two main areas that were identified in the first two workshops are:

- Socially Aware Ambient Intelligence
- Privacy, Trust, and Identity

and will be described in the following two sections in more detail.

2.1.1 Socially Aware Ambient Intelligence

Social awareness characterizes interactions and patterns of responses of persons who are community minded and socially active in their social context. This includes communication between humans as part of a more comprehensive social dialog which can also involve different artefacts as part of a socially aware system. This system can be characterized by having a sense of involvement, knowledge about the general and actual social behaviour of other persons along with their degree of attention, desire for customization and control, emotional state and interests as well as their desire to engage in social interactions. Social context influences how something is perceived, interpreted and then used in a follow-up activity. From a social sciences point of view, social context is being regarded as a sequence of interaction and communication turns taken between participants. This means that social context is dynamic and constructed by individuals through their actions. Social context can be quantified using various spatial (person's physical position in time and place), organizational (person's position in social hierarchy), and situation variables known as social context cues or social signals. (We do not want to go into the details of a definition of 'social context' in this document, being aware of the problems of defining different types of 'context' and at some point even differentiating it from 'content'.) Situational variables describe the characteristics of the immediate communication context including dynamic changes and participant notifications. These may include demographic characteristics of the communicators such as age, gender, race, socio-economic status, residence and such personal characteristics like appearance, accent and tone of voice, mood, facial movement, size, gesture and attitude.

Given this background, the goal of building a socially aware ambient intelligence system is to create a collection of smart artefacts constituting an ambient environment that understands social signalling and social context resulting in the capability of improving social orientation, collective decision making while keeping local and remote participants in the loop.
Some of the ***research challenges and requirements for socially aware ambient systems*** can be characterized as follows:

- Build systems that understand social signalling and social context as a constraint as well as an activity opportunity (=> need to model community-minded and social behaviour)
- Keep humans in the loop and facilitate them with options for informed and mature decision-making by moving away from fully automated systems and instead promoting people-oriented, empowering smartness
- Improve collective decision making and extend to involve remote humans in the loop (=> e.g., self-help support groups)
- Provide infrastructures that enable intercommunication of a wide range of devices, sensors, actuators and a functional coordination and intelligent scheduling in a self-organizing fashion
- Integrate reflexive systems for semantic interpretation of contexts, user preferences and profiles
- Extend to group-oriented interfaces: one person => groups and teams => communities
- Consider multiple-devices, multiple-people, multiple contexts

Using these objectives as guidelines, one has to investigate what kind of technical basis and infrastructure is helpful for meeting these requirements.

2.1.2 Privacy, Trust, and Identity

In today's connected world, where computers mediate frequently our interaction and communication with the outside world, many people suffer from the 'Big Brother' syndrome. Especially privacy is an elusive concept because not everyone's sense of privacy is the same. Moreover, the notion of privacy is unstable because people's perception of privacy is situation specific or more general context-dependent. People's expectations of privacy may differ according to many factors and situations. There are many definitions for privacy, starting from the end of 19th century. According to Warren and Brandeis privacy is "the right to be let alone"; Alan Westin considers privacy as "the claims for individuals, groups or institutions to determine for themselves when, how and to what extent information about them is communicated to others". Wikipedia summarizes the concept of privacy as "the ability of an individual or group to keep their lives and personal affairs out of public view or to control the flow of information about them" and distinguishes between "physical", "informational" and "organisational" privacy. In this context, we are primarily concerned with the second one but the other aspects play an important role as well.

In the context of the research efforts discussed in this white paper, the issues of changing views on privacy, trust and identity are mainly a result of the tricky trade-off for creating smartness. It is becoming more and more obvious that there is an interaction and balance/ trade-off between

- being able to provide intelligent support based on collecting sensor data and using them for selecting and tailoring functionality to make the system "smart"
  and
- the right of people to be in control over which data are being collected, by whom, how they are being used, where, when, etc.

There is the danger that we are moving from a situation where people considered privacy as a legal and moral right (and sometimes a socially negotiated feature) to a situation where it becomes a commodity to be traded or being paid for and thus a privilege for those who can afford it.

Some of the ***research challenges and requirements for Privacy Enhancing Technologies (PETs)*** can be characterized as follows:

- Overcome the privacy/trust/security concerns of people by initiating an open dialogue and providing transparency about system design decisions. The question "why the data is being collected" is becoming more and more a focus of attention.
- Address the conflict of ubiquitous and unobtrusive data collection/provision with human control and attention in an open fashion and make it part of system design
- Build and integrate Privacy Enhancing Technologies (PETs) that respect the moral and legal rights of people in current and future sensor-enriched (-polluted?) ambient environments
- Explore existing solutions in this area as interrelated and even competing issues and go beyond because current solutions do not provide the needed safeguards in an upcoming AmI-world because the basic criteria (anonymity, pseudonymity, unlinkability, and unobservability), identified in network applications, are much harder to be achieved in an AmI world

2.2 The driving vision: Towards "The Humane City"

The new issues and challenges that were identified on the basis of the STAR results were still at a general level. Thus, it was necessary to become more specific. One way of doing this, is to orient oneself via demanding application scenarios. Based on the discussions in the previous workshops, the theme of *Urban Life Management in Smart Cities* was selected as an umbrella scenario. Based on this, we developed the concept of "*The Humane City*" as our vision for the *City of the Future* and the future of *Urban Living*.

The relevance of the umbrella scenario "Urban Life Management" should be obvious not only for experts in the related fields of architecture, city planning, sociology, and economics. People speak of an *Urban Age* that we have entered and predict that the national prosperity will largely depend on the abilities of cities to reach their full potential. Nevertheless, we like to substantiate the obvious relevance by the following facts:

(1) Half the world's population lived in urban areas by the end of 2008 and about 70 percent will be city dwellers by 2050, with cities and towns in Asia and Africa registering the biggest growth, according to the latest U.N. projections. Thus, the year 2008 was a turning point in human history, as more than half of the world's population lived in cities.

(2) According to the U.N. estimate, world population is expected to increase from 6.7 billion in 2007 to 9.2 billion in 2050. During the same time period, the report stated that the population living in urban areas is projected to rise from 3.3 billion to 6.4 billion. Greater Tokyo is considered to be the largest mega city with 35 million, which is greater than the entire population of Canada.

(3) Cities are becoming increasingly the most relevant places to observe and to understand for instantiating and influencing changes in all fields of economy and society.

(4) Already today, cities are the world's centres of excellence, bringing together people from many areas of life acting as important opinion leaders and initiators of change and providers of new opportunities. At the same time, they are also the target of many people – often with socially deprived backgrounds - hoping for new chances and a better life for themselves and their children. Cities provide opportunities, economies of scale, a future with more choices.

(5) On the other hand, cities are also seen as being responsible for creating and exhibiting the divide between rich and poor, diminishing their quality of life, for marginalising communities, and for causing environmental hazards. They have been castigated as centres of disease, social unrest, instability, and insecurity.

(6) Because cities host many more people compared to their originally planned dimensions and grow faster than their infrastructure, cities face high risks from industrial hazards, natural disasters, and the spectre of global warming.

In summary: A successful city of the future (however "successful" can be defined in detail in this context) will have to balance social, economic and environmental needs and has to respond to pressures from all sides. A successful city should offer an appropriate infrastructure (including transportation, communication, water, energy, electricity, etc.) and thus also providing efficient support for carrying out the different activities. It should offer opportunities and quality of life to all social classes; provide motivation and security for investors to develop new initiatives, provide a stimulating atmosphere for new ideas in business, science, education, culture, entertainment, media, etc. It should put the needs of its citizens at the forefront of all its planning activities. A successful city recognises its natural assets, its citizens and its environment and builds on these to ensure the best possible returns.

2.2.1 Smart Cities: Today and in the Future

The general issues that were addressed above (of course, only in a limited way) are more and more acknowledged by a wide range of people. A detailed analysis would obviously be beyond the scope of this white paper. Nevertheless, they provide an excellent framework, rationale and motivation for formulating challenges that we pose now in the context of future research agendas for Information and Communication Technology (ICT) in general and in particular in the context of the focus of this working group:

"How can the realization of a Smart City contribute to reducing and potentially even avoiding some of the problems that are faced by today's cities and in the future?"

Or in other words:

"How can ambient and ubiquitous ICT help to contribute to Urban Life Management?

This can be analysed and has to be investigated from the following two perspectives:

- How to manage a person's / a group's life in today's and future cities?
- How to manage the urban environment of today's and future cities?

While formulating it as two perspectives, it should be clear that they are not independent; but it helps to identify the different user needs depending on who are the users:

- People living and working in the city; searching, checking, evaluating and then utilizing the services that are offered by the urban environment with respect to the different aspects of life
- People who are organizing and administering the urban infrastructure so that the services are available for citizens and visitors.

Examples of how the smart city of the future could operate are: taking care of its individual inhabitants by offering personalized services (e.g. for security, health and administration, but also for leisure, shopping, …), by providing optimized opportunities of transportation by combining various sources of traffic information at the same time and integrating different means of transportation, by providing opportunities for the involvement of people in the community, e.g., by matching people on the basis of common interests and suggesting common activities or in other words: offering multiple opportunities to be an active part of society. These are only a few examples and more are being developed.

One also has to note that there are already some efforts to realize Smart Cities, in particular in Asia. For example: the "u-Cities" (ubiquitous cities) programme in Korea, the Ubiquitous Networking Forum and the notion of a "U-Japan" in Japan, and the iN-2015 Masterplan of an "Intelligent Nation Singapore". Research in this area is concerned with the creation of a future society in this kind of Smart Cities. In Europe, one can mention as examples the EU-funded integrated project IPCity addressing interaction and presence in urban environments and the German T-City Friedrichshafen, a practice experiment of the German Telekom. Besides technical issues such as the usage of different broadband networks and interoperability of devices, social impact and social mobility combined with universal access in Smart Cites should be more in the focus of the research efforts. This includes also the change or even disappearance of the traditional orientation "metaphors" based on place and time. The definition of methods for data provision and privacy and security restrictions, the identification of new stakeholders, and the understanding of upcoming social interaction principles will have to be discussed intensely.

2.2.2 Towards The Humane City

As we pointed out above, more than half of the world's population lives in urban areas. Therefore it is not only important but also urgent to investigate what kind of city we would like to realize when utilizing and developing information technologies. A city is a place where people gather, live and work. During their daily life they communicate with each other, exchange various kinds of information. They discuss a wide range of aspects of everyday life issues, economical issues, and political issues. They attend events together and enjoy entertainment together. In their business contexts, they share and discuss information, work together in distributed environment as well as in face-to-face environments.

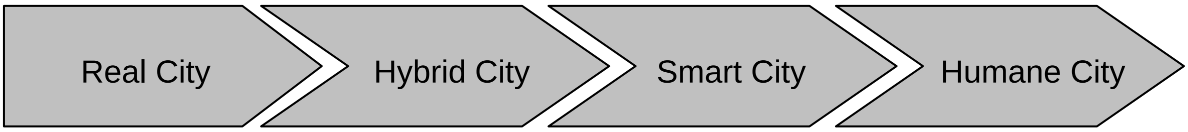
We have the vision that this city should be a city where people enjoy everyday life and work, have multiple opportunities to exploit their human potential and lead a creative life. Thus, we call it "*The Humane City*" in order to add another dimension (e.g., addressing values) to the more technical notions of a "smart" and a "hybrid" city. The question now is: how can information and communication technologies support people in such a humane city? The basis is, of course, to supply an infrastructure for the tight communication among people, so that people can share any information they want, easily exchange opinions, achieve discussions among huge numbers of people, and reach a mutual understanding/agreement through their communication. In addition to the complete freedom to access any type of information, the security and privacy of people should be strictly protected so that people can trust each other and also have trust in the integrity of the basic infrastructure and the services provided a range of different service providers, be it the city or private companies. In the work and business context, the infrastructures and the services should support any type of work place design and buildings and multiple forms and modes of work and collaboration as individuals, groups, teams, or organizations.

It is interesting to note that this concept of a Humane City somehow resembles several aspects of the concept of old Greek city states such as Athens, Sparta, etc. Although the size of such a city state is far smaller than a city in the modern era, all information was shared among the citizens in these cities and various kinds of decisions were carried out through the discussion of all people in the city. A key facilitator was the institution of the 'agora', a marketplace and open meeting place surrounded by public buildings, usually in the centre of Greek cities and towns. The agora served the purpose of trading goods as well as being a place for meeting family and friends for a chat, for business people to make theirs deals. Furthermore, it was a place of shaping the public opinion, where citizens could listen to and join in discussions about community and political issues. It can be considered the hub of ancient Greek civilization and the birthplace of the concept of democracy. In this atmosphere of freedom, mutual trust, and dignity of each person, the old Greek culture was created and became the foundation of many cultures all over the world.

Of course, there are differences between the ancient Greek city and the future *Humane City*, most importantly is their "size." Each Humane City is far larger than the old Greek cities. Other differences are the types and distribution of available infrastructures within and beyond the city limits (if they still exist at all). For example, all Humane Cities are connected through networks and thus compose a Networked Humane City at a global level. And then, there are differences at other levels, e.g., the types of stakeholders in the community. The big challenge in the 21st century is, how to realize this Humane City utilizing and developing information technologies.

2.2.3 Key Dimensions of Humane Cities

While the notion of the "Humane" City describes the character of what it should be in terms of requirements for the communication, interaction, collaboration and social networking opportunities, one also has to look at the basis and the technical aspects for its realization. In a nutshell and necessarily simplified, one can summarize the development from an 'ordinary' city to a 'humane' city by the following progression:



Extrapolating from what we know today, the Humane City will be based on the following three progressive steps which in some areas and to some degree are realized in parallel.

1. The first step is (or was, because it is already happening today to some degree) the extension of the real city into the virtual world. The integration of real and virtual parts – complementing each other – results in the *Hybrid City*.

2. The second step is the transformation of the different types of services that are available in our current cities into smart services and thus the city into a *Smart City*

3. The third step is the adoption of certain requirements during its realization so that we do not end up with a technocratic Smart City which is monitoring and controlling its citizens in the interest of only a few stakeholders creating a "big brother" society. The realization of a Humane City facilitates opportunities to keep the citizens in the loop of decisions, to empower them and to provide socially aware smart environments where privacy and trust are respected values and provide the basis for fostering a creative, all-inclusive and humane society with a high quality of life.

We now describe the different dimensions a little bit more in detail. The overview is provided in figure 2 (see below). There are more than the dimensions shown in the diagram.

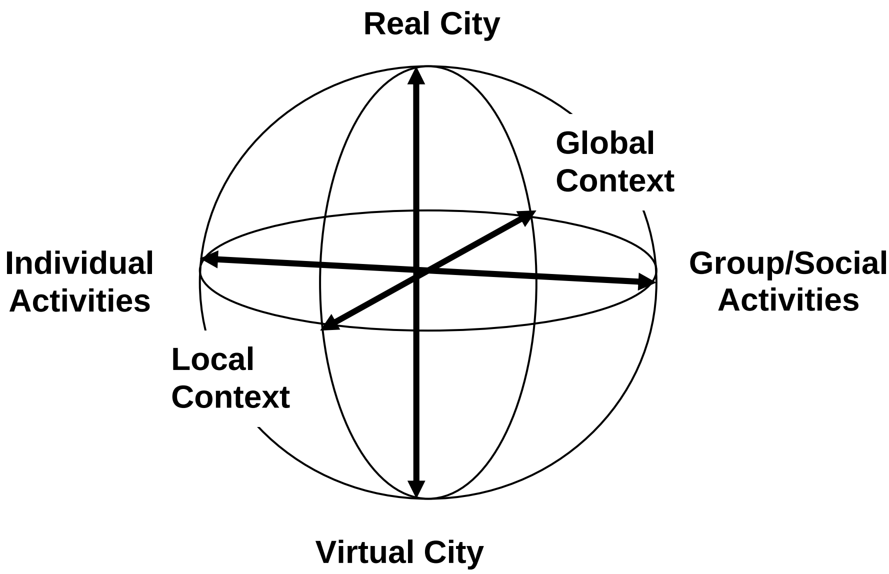
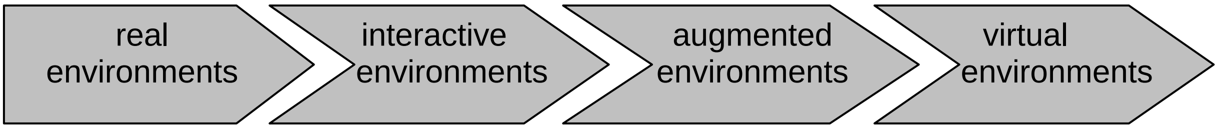


Figure 2 Three Key Dimensions of Humane Cities (there are more but not depicted here)

A *Hybrid City* consists of a *real city* with its physical entities and real inhabitants and a parallel *virtual city* of counterparts of all real entities and people. The parallel virtual city will not be a complete model of the real city. It will be, on the one hand, only a reduced model and, on the other hand, it will contain additional information not readily available in the real world or entities that are different from or do not "exist" in the real world. Thus, we can state that there will be a continuous dimension with "real" and virtual" as its end points as indicated in figure 2.

- ***Reality Dimension:***



In part, new forms of information flow will be able to replace today's material flow using quality of life services that are personalized and ubiquitous available. Although being aware of all kinds of current developments that are labelled as Web 2.0 and the like, we do not identify them as our target area for our white paper. As a general strategy, we rather favour here more the notion of *Augmented Reality* vs. Virtual Reality resulting in *Urban Mixed Realities*. Tangible smarts artefacts and tangible interaction will be key for the interaction and presence in urban environments and for building a Humane City which will be a Hybrid City

The other two dimensions in figure 2 that we find useful when characterizing the proposed notion of Humane Cities are the distinction between "local context" and "global context", on the one hand, and between "individual activities" and "group/social activities" on the other hand.
:

- ***Space/Place/Context Dimension:***

The second dimension provides the opportunity for discussing differences in the contextual sphere of where the interaction happens, where services are provided or being used and their operating range in terms of proximity, being close or distant. This is related to similar categories used in CSCW (computer-supported cooperative work), but this time extended from work activities to all kinds of activities that are undertaken by people in a city. It has to be addressed when discussing the different spheres of place and space. Examples are shown in the diagram.

- ***People Dimension*:**

The third dimension in figure 2 addresses the distinctions between the number and social relationships of people involved. Although grouping all the different possible options into only one dimension might be a limited view and not adequate for reflecting the large variety in terms of number, structure, cohesion, relationships, and quality, this "people" dimension serves as a good indicator to address the different social ranges of people's activities. Examples are shown in the diagram.

While personalized services and information have to be provided in an intuitive way, being easily understood, avoiding complex graphics and meaningless numbers or letters, the maybe biggest challenge will be the (social) inclusion of smart cities' inhabitants, guaranteeing their active participations instead of transforming them into passive receivers of information, decisions, and services. It includes also finding methods for improving the ways in which people can relate to the urban environment and to other people.

- ***Smartness Dimension:***

People-Oriented, Empowering Smartness	**vs.**	System-Oriented, Importunate Smartness

A fourth dimension which is not visualized in figure 2, is related to the type of Smartness. It addresses the discussion on the degree of automation and the potential loss of control of humans in smart environments. We have contrasted this earlier as System-oriented, importunate smartness vs. People-oriented, empowering smartness.
The important aspect of this dimension is to which degree is the human still in the loop, having influence and making decisions. The degree of smartness and automation is also related to the issue that individualization (on the basis of personal data, and personalized needs and preferences) has to be balanced against social concerns and environmental issues. Looking at the different dimensions, we can see again the relevance of the two major themes we have identified before: "socially aware ambient intelligence" and "privacy, trust and identity"

2.2.4 Sample Scenarios

In order to make the umbrella scenario more concrete so that it becomes tangible, we have to identify concrete examples of potential future environments and services. Then, we are able to make proposals for the corresponding infrastructures in terms of the technical paradigms and applications built on top of them and social rules and mechanisms, etc. in terms of organizing and managing the urban life in the future city.

Realizing the above mentioned challenges, new and innovative scenarios and use-cases are necessary. In order to stimulate the discussion, a few scenario examples are described here without any attempt to determine the discussion at the workshop:

(1) *Smart Transportation*
Travellers in smart cities can be informed at every time about possible means of transportation taking the location and schedules into account, including information about changes in timetables, offering alternatives that are either cheaper and/or faster. Furthermore, the offered information will consider the general traffic conditions and the travel's impact on the environment situation.

(2) *Health Monitoring and Medical Therapy*
Doctors and medical staff will be able to inform themselves (and the patient) about the patient medical condition, considering her/his medical history, nutrition habits and family situation. A comprehensive usage of this information will allow an integrated medical therapy – in emergency situations as well as in routine practice - that will dramatically change peoples' health condition, social inclusion, and personal attitude.

(3) *Responsible Citizenship: Facilitating Engagement and Involvement*
People will be enabled to play an active part in smart city's society by being offered social participation in various ways. This includes more standard forms of leisure proposals (e.g., museum, theatre, exhibitions that fit to individual personal interests) that can be also shared by people who don't know each other before, but also more advanced forms of proposals to get involved in and contribute to the community, to take part in social activities, etc. This kind of participation will be available everywhere and every time in order to offer opportunities for social inclusion and involvement in a continuous fashion and in an informal and ad-hoc way.

Additional sample scenarios can be proposed and discussed through the inspection of the three sub-themes that were identified at the Tokyo workshop. They are described in the next section.

2.2.5 Identification of Sub-Themes

The third workshop (held in Tokyo in June 2008) identified the following three sub-themes: 1) Tangible emotion, 2) Smart spaces as distributed cognitive systems, and 3) Social networks in virtual spaces. They built the basis for the development of the 12 Research Lines that were discussed and proposed in the follow-up workshop in Cannes and are presented later on in Chapter 3. It has to be noted that the extension and transformation from the notions of Hybrid and Smart Cities to that of Humane Cities was one of the important results of the Tokyo workshop, in particular outgrowing from the first sub-theme.

Tangible Emotion

Tangible emotion is a new approach for communicating emotions. The underlying rationale is twofold: on the one hand, emotions can be triggered by tangible objects while, on the other hand, tangible objects can be used for expressing emotions. Tangible emotions are thus beyond the visual and auditory senses that are primarily used in communication. Furthermore, in the context of the discussion of this workshop, we like to emphasize in general the role of emotions in human-computer interaction and the role of computers for capturing and sharing emotions. Tangible interfaces are prominently used in games and entertainment applications where one is confronted with another aspect: fun, sometimes only 5 seconds, sometimes more. The fun factor of using tangible devices cannot be underestimated. Taking this at a more general level, we propose that people should have every now and then '5 seconds of fun' in their everyday life, a proposal that can be used as a principle in graphical user-interface design but also beyond and extended to physical space. Experiencing fun is often based on a surprise effect, being unconventional. Putting both aspects together (tangible emotion and fun) we argue for using tangible emotion interfaces creating positive feelings. Emotional design will make the transfer of humour, of feeling alive, or of enlightenment possible by breaking conventions.

Applying these considerations to the topic of "smart cities", we asked in the Tokyo workshop: How about an "affective city" that goes beyond or better complements the smart city? We argued therefore for a "*humane city*" that provides a 'creative and emotional superhighway' combining smart and fun elements. Naturally, this approach raises a number of new research issues. Sensing and actuation addressing all levels of all human senses provides new opportunities. This could result in a toolkit for supporting creative activities and for expressing emotions. While the approach intends to be applied to the general public, one has to take the range of individual differences into account. Obviously, different people are expressing their emotions in different ways. Thus, personalized mappings of emotion to devices, the control of emotion and the sharing of emotion have to be differentiated and specified. Rules have to be identified for expressing emotions regarding different cultural background of users and/or different individual situations like negative or positive stress. The realization of tangible emotion is a multi-disciplinary task that has to involve consumer product designers, artists, psychologists, architects, structural engineers, ubiquitous computing researchers, ethnographers and cultural studies experts. Applications and solutions in this area should be provided by the public as well as the private sector.

Smart Spaces as Distributed Cognitive Systems for Individual and Social interaction

The starting point for this sub-theme was the "symmetric interaction between virtual and real spaces (with a focus on actuators, embodiment, enactment)" but one has to go beyond present-day smart space research. As a result, smart spaces were conceptualized as cognitive systems endowed with agent and federated perception-action capabilities so that they could – in principle - act in an autonomous way. This kind of smart spaces will be augmented by autonomous objects that are incorporated in every-day-life objects constituting the space, e.g., furniture. As an intermediary stage, one could imagine using robots and smart spaces together complementing each other. To achieve this, one can take two perspectives:

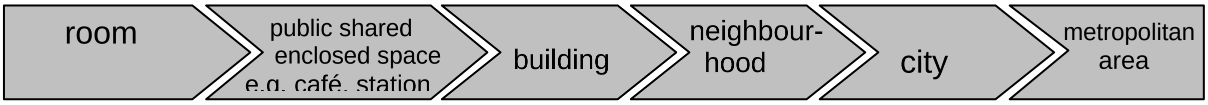
- *augmenting smart space environments with robots*
- *augmenting robots with smart space environments*

It is obvious from this description that this view indicates close relationship to the topics of WG 3 (see also the Chapter 4 on Cross-Thematic Synergies). Smart spaces will act in an autonomous way, tracking objects and persons in order to adapt itself to the global room situation, its persons, and the current situation (e.g. activity of persons, individual device configurations, etc.). Autonomous behaviour of smart spaces is characterized by a growing capability of information processing, of self-learning and self-configuration (for adapting to new devices and situation), and by adapting itself to necessary privacy requirements. Self-management (of the devices involved and its capabilities) and self-healing (e.g., in cases where devices are malfunctioning) are other important qualities of these envisioned smart spaces.

Bidirectional coupled learning between human users and smart spaces will be facilitated by way of physical interaction. This kind of bidirectional relationship will allow that smart spaces can learn from reactions of the users (e.g., by interpreting the emotional status) and can provide additional feedback by means of actuated physical objects. This kind of self-learning behaviour could start an artificial meta-learning effect, when using a more diverse repertoire of actuation capabilities.

Smart spaces will allow spontaneous social interaction of different people via physical information sharing and 'stigmergic' communication. (stigmergy = interaction by way of the physical environment). Spontaneous social interaction and distributed cognition will be possible; but also the sharing of capabilities of different smart spaces.

The smart space provides to its (temporary) inhabitants scaffolding and physical support for distributed cognition and ways for sharing information and stimulating communication. While the term "smart space" is usually used with reference to "rooms", one has to consider the scaling-up of smart spaces as it was already introduced earlier with the *Space/ Place/Context Dimension* (see diagram):



Person-to-person interaction and person-to-system interaction should be provided at each level of this scale. It is assumed that the larger the scale of the smart space is, the more multi-purpose the interaction will be and the more varied the potential interaction means.

Social Networks in Virtual Spaces and Physical Proximity

Social networks in virtual spaces provide new opportunities. They facilitate virtual connections between people who either know each other already or – and this is the new quality - did not know each other beforehand. The scope can vary from short ad-hoc formations (about 30 minutes) to midterm and long term network formations. This kind of connections results often in forming digital communities. A major characteristic is that they are usually decoupled from real space encounters (see below). The trend shows an increase in number and time of connections and interactions, playing an increasing role and going beyond the social interaction mechanisms of today. The current Web 2.0 social communities are representing the starting point. Beyond just connecting, these social networks provide also a range of new opportunities for expressing emotions and for being a creative person. It should be noted that there are also immense opportunities for monitoring the interaction and communication of people in an unprecedented way which raises increasingly issues of privacy (although in many cases especially young people do not seem to care about these implications at all). At the same time, new identities, groups, or relationships can emerge that have no correspondence with real people. Then, the issue of privacy becomes less important or even obsolete because they are virtual-only characters.

A major goal for using the potential of social networks in virtual spaces could be the facilitation of "co-creative societies" fostering social creativity and collaboration and personal expression. But this will require an additional 'grounding' in real space and with real people. While the decoupling from real physical space is novel and can be of added value for some issues, the real-virtual combination seems to be more promising. Within our framework of "hybrid cities", we argue for a coupling real-world phenomena and social networks in virtual space. They can provide support for taking multiple, possibly serendipitous, local interactions and reactions to create global observable phenomena/change, for example, in the area of monitoring phenomena in the real world: garbage, crime, carbon footprint, resource usage.

The creation of new virtual social networks will have implications for forming corresponding or partially overlapping social networks in the real world and address the issue of physical proximity. They can be exploited for creating innovations in commercial/business sectors and for personal issues. But the actual impact of transferring virtual social networks to the real world is not clear. Another interesting issue is the potential incorporation of artificial members/agents that are no avatars of real people into these social networks. Will these members play a role in the counter part real physical world? And the other way around: will robots (or other artificial real objects) be included in the virtual social networks and what is their role?

There are also more technical oriented questions to be considered: Are there metrics (e.g., from network research) available and usable which are able to describe these kinds of social interaction? Will new communication behaviour have an impact on network structure and technology, or will the technical conditions maintain the way of communication behaviour? In case such networks could be visualized for making dissemination of information transparent; could this kind of measurement be used for monitoring actions of social communities? Obviously new evaluation methods based on new properties of monitoring people's traces in both physical and virtual spaces are needed in order to understand the social consequences of emerging social networks.
Finally, privacy and trust, the question of (physical and social) identities and the maintenance of existing identities will play a major role to be considered when developing, establishing and participating in this kind of communities and networks.

3 Proposals for new Research Themes

Based on the umbrella scenario of "urban life management", serving as an important frame of reference, we identified the issues (deficits and challenges) that resulted from the previous discussions and considerations. The challenges we are facing when developing *"Humane Cities"* confront us at various levels. One way of investigating them is to state general *Goals for designing a Humane City*. They include:

- to enable the development of a humane and creative society
- to facilitate social interaction and communication
- to foster social creativity and collaboration
- to facilitate social networks in real and virtual spaces
- to facilitate personal expression
- to address emotional and affective aspects
- to address and involve all our human senses
- to keep the human in the loop
- to assure privacy and trust

We identified the following 12 Research Lines, where R1 addresses more global issues of the rationale and conceptual basis for designing "humane cities" while R11 and R12 are more 'horizontal' aspects that are also relevant for the other research lines. They are a result of the discussions at the different workshops, especially at the Cannes Workshop, and the follow-up on-line elaborations and discussions in small groups of the participants for individual research lines with the Working Group leaders.

The following participants of the Cannes Workshop contributed actively to the formulations of the research lines: Mark Billinghurst, Adrian Cheok, Dimitris Grammenos, Alois Ferscha, Nuno Guimaraes, Masa Inakage, Antonio Krüger, Seongil Lee, Christian Müller-Tomfelde, Ryohei Nakatsu, Gilles Privat, Ted Selker, Norbert Streitz, Reiner Wichert, Kin Choong Yow.

- *R1: Rationale for the Humane City*
- *R2: Tangible Interaction and Implicit vs. Explicit Interaction*
- *R3: Hybrid Symmetric Interaction*
- *R4: Space-Time Dispersed Interfaces*
- *R5: Crowd and Swarm Based Interaction*
- *R6: Spatial and Embodied Smartness*
- *R7: Awareness and Feedback Technologies*
- *R8: Emotion Processing*
- *R9: Social Networks and Collective Intelligence*
- *R10: Self Organization in Socially Aware Systems*
- *R11: Realization and User Experience of Privacy and Trust*
- *R12: The Scaling Issue*

3.1 R1 - Rationale for the Humane City

As we elaborated before in section 2.2, the notions of hybrid city and smart city provide rather functional perspectives. Therefore, we proposed the extension and transformation towards "Humane Cities". Humane involves here also democratic as well as emotional and seemingly irrational aspects in our everyday life and allows us to address further requirements. The realization of a Humane City should facilitate opportunities to keep the citizens in the loop of decisions, to empower them and to provide socially aware smart environments where privacy and trust are respected values and provide the basis for fostering a creative, all-inclusive and humane society ensuring a high quality of life. In order to achieve these goals, it is important to form a solid theoretical basis for these aspects of human activities carried out in the complex network of artefacts and environments. Therefore, we propose this Research Line R1 on the rationale with the objective to chart this still unknown territory of a theoretical foundation of what constitutes Humane Cities. It should be noted that this research line has to be carried out via cross-disciplinary collaboration and in a multi-cultural team.

While there is the challenge to develop an overall rationale for designing humane cities, it is still valuable to address selected aspects. In the following, we list some examples. There is a need to establish design theories and methodologies that involve communicative environments for human-to-human emotional communication and for human-to-smart artefact interaction in the anticipated humane environments. Another challenge is to develop design theories and methodologies that relate to "time". In our connected, humane society, we will be combining synchronous and asynchronous communication. It is crucial to design how time can be expanded and redefined. Some of this will be addressed in more detail in Research Line R4 on Space-Time Dispersed Interfaces. There exist a large number of games as examples of entertainment, but we still miss a substantial investigation of collective entertainment and its role in society. This requires design theories and methodologies for our pleasurable everyday life. It involves the design of folksonomy or collectivity in a dynamic, real-time smart environment.

While these issues are more geared towards the emotional and fun-related aspects of human life, there is also the issue of the range of people we are addressing with the humane city. Citywide installed AmI-technologies have the potential of providing a friendly “face” to today’s faceless urban environments, making them more humane and inclusive. The reason for this is two-fold. On the one hand, AmI technologies can proactively (and collaboratively, with the help of humans) anticipate human needs and cater for them. On the other hand, AmI technologies provide humans with the opportunity to directly interact with their surrounding environment and use it, or even change it, according to their needs. An absolute prerequisite for supporting any type of (explicit or implicit) citizen-city interaction is Universal Access, i.e., the ability of all people to access AmI-technologies at a physical, sensory and cognitive level. In other words, AmI-technologies should be aware of the vast diversity of the human factor and be able to recognize, understand and eventually adapt to its various manifestations. At this point, it should be clarified that Universal Access does not only refer to people with disabilities. It is used as an all-encompassing theme that includes people whose characteristics may hinder use of AmI technologies, such as for example young children, elderly people, people speaking different languages, technology agnostics, etc.

In this context, a fundamental research topic is how to design universally accessible large-scale heterogeneous AmI environments. The key challenge lies in the fact that such environments are very likely to be inhabited by “users” with very different – and often conflicting – needs and goals. Thus, the ways that the environment will be able to adapt in order to achieve Universal Access for concurrently all of its inhabitants is an open issue. Some indicative ideas might include striving for a minimum level of common accessibility (which might require downgrading the accessibility level of some people in favour of the global community accessibility level), or even using transient personal accessibility “tokens”, where the environment temporarily best adapts to one or more particular cases based on some prioritized criteria (e.g., when a person’s safety is at stake due to accessibility hurdles).

Another but not less important aspect determining the rationale of the Humane City is the issue of citizen participation and their active role in designing the humane city. This includes their role in determining the type and extent of which services are provided and to which conditions as well as the degree of privacy and trust that is ensured. The details of the latter is the topic of the dedicated Research Line R11.

3.2 R2 – R5: Four Research Lines on New Interaction Paradigms

Technological progress and informational needs have made cities the places on planet with the highest density of ICT deployed into the environment. Today’s megacities appear as gigantic landscapes of interfaces of diverse purpose (protecting, guiding, exposing, controlling, etc.), service (logistics, commerce, energy, resource supply, traffic and transport, work and labour, culture, art etc.), utility (personal, public, well-being, environmental conditions, quality of life, etc.), appearance (displays, signs, alarms, buildings and streets, doors and gates, vehicles, etc.), mobility (stationary, mobile) and modality of perception (visual, auditory, olfactory, gustatory and tactile). This overwhelming heterogeneity and ever growing penetration of ICT-controlled interfaces in cities poses interaction challenges to citizens that have never been encountered before in any other context. Living, working, moving – literally every form of human engagement – involves the interaction, intended or accidentally, with a complex multitude of interfaces. The claim for intuitive, un-obtrusive and distraction free interaction with such technology-rich environments approaches a whole new dimension in megacities. In an attempt of bringing interaction "back to the real world" after an era of "explicit ICT" (computers with keyboard and screen interaction, mobile phones, vending machines, info booths, etc.), new interaction paradigms will have been designed, developed and deployed, engaging a more "implicit ICT", and interfaces that are both dispersed in space (in different places in the city), but also in time (i.e. interfaces that allow for interaction that decouples the cause and the effect of an interaction in time).

Not the intentive interaction at the level of text, command, or choice input, but rather the implicit interaction based on the mere presence, absence, movement, bypassing, glimpsing, watching, pointing, touching, directing, talking etc. will make (background) systems react, remember, invoke services etc. "The interface" in such settings will have to be understood as embedded, meshed with very many other interfaces, interoperating with many different action triggers, and operating in the background. The set of all physical objects present in the environment will be understood as the "interface" – while representing information, at the same time also acting as a control for directly manipulating that information or underlying associations. With this seamless integration of representation and control into a physical artefact also input and output device fall together. Placed meaningfully, such artefacts can exploit physical affordances suggesting and guiding user actions, while not compromising existing artefact use and habits of the user.

These observations resulted in the formulation of four Research Lines (R2, R3, R4, R5) that address the need for new Interaction Paradigms as described in the next four sections.

3.3 R2 - Tangible Interaction and Implicit vs. Explicit Interaction

Ambient Intelligence (AmI) is about smart, adaptive environments which react to the actions of people and objects and their needs. This vision considers the entire environment – including every single physical object – and connects it to the interaction of people within the environment. Thus, it is important to conducted research on how to support intuitive interaction between people and their environment and how this can lead to enhanced efficiency, increased creativity, and increased well-being.

In an AmI environment different sensors and processing devices embedded in the real world collectively work together over an interconnected network, using distributed information and intelligence. In this way, the environment is able to recognise the people in it, to identify their individual needs, learn from their behaviour, and to act and react in their best interests.

3.3.1 Implicit and Explicit Interaction

There are a number of key differences between interaction with a traditional desktop interface and in an AmI environment. The interaction concepts for controlling AmI environments will be implemented by networks of computing nodes interpreting the instructions of the user, and distributing them via communication infrastructures to the end devices that can implement the task best. The interaction in the AmI environment is decoupled from the hardware. The user no longer gives commands to control devices, but he or she defines objectives which are then interpreted and (more or less) automatically implemented by the AmI system.

However, the key difference is the need for supporting both Explicit and Implicit interaction. In a desktop interface the user makes explicit commands (such as moving the mouse) to interact with the system. Explicit input is still important in AmI systems, but these systems also recognize implicit interactions like signals from movement sensors or microphones that infer user actions from capturing sensor data. The application of sensing and recognition technologies provides environments with more and more communication that is of implicit nature. This information is coming from highly distributed devices and is available in many form factors and modalities. The challenge is to coordinate across many output locations and modalities without overwhelming the limited attention spans of people. The often not transparent relationship between input and output is important in Ambient Intelligence, because technology's invisible nature can be used for smooth integration between the physical and virtual worlds.

To support the acceptance of such reactive AmI environments the user has to be involved in the loop by implicit interaction metaphors like interfaces for speech recognition, 3D interactive video interfaces, emotional interfaces for robots, or tangible interfaces. Natural forms of interaction will have a crucial impact on the everyday life of the user. A lot of research had been done in the past on intuitive interfaces, but most of them in voice and gesture recognition and there has been little research in interface methods for AmI applications. Thus the most important topic is to make these interaction metaphors more intuitive to reach the goal of the acceptance of the users.

3.3.2 Tangible interaction

One interaction metaphor that is ideally suited for AmI applications is where a person interacts with digital information through the physical environment using Tangible User Interfaces (TUI). A Tangible User Interface is one where a user manipulates a real physical object to interact with digital data, and thus allows the user to interact with an AmI environment through manipulating the environment itself. For example, users may lay the physical mobile phone on a table to start a video conference on a wall-sized display or to put the physical camera on it to show pictures on this display. Using a TUI approach allows the AmI developer to have some design guidelines to work from.

Thus this Interaction Research Line provides a number of important sub-topics that should be studied as future research challenges:

- How can tangible interaction techniques best be used to interact with AmI interfaces?
- What Explicit and Implicit interaction metaphors are best suited to AmI applications?
- How can AmI interaction methods be evaluated?

3.4 R3 - Hybrid Symmetric Interaction

Users' actions in real and virtual environments are often neither consistent nor can they be considered being symmetrical or reciprocal. These aspects become particular important for hybrid environments in which no particular environment/ world prevails. Usually consistency is achieved when users explicitly update information in one or multiple virtual environments according to changes in the real world. For example, when moving a real paper document from the desktop into the bin, the representation of the document in the virtual environment becomes deleted as well. Sensors and mechanisms are conceivable to maintain this sort of consistency from actions in real to virtual environments. However, symmetry of the interactions, i.e., the maintenance of mutual consistency even from the virtual to the real world is more sophisticated and very difficult to accomplish. Through the recent deployment of sensors in physical environments, changes in the physical environment can be reflected easily in the virtual environment. For example, keeping track of GPS-measured locations of vehicles in a public transportation network can easily be recorded and visualised in a virtual representation of geographic space (e.g., in Google Earth). More complicated, however, is the other direction: changing physical states due to virtual sensor measurements or virtual actions. One could imagine that by indicating destinations in the virtual, passengers could be able to alternate the route of public transportation vehicles taking in the real world.

The research line focuses on the investigation of particular interactions in hybrid environment that are symmetric, i.e., maintaining consistency of the representation no matter in which environment the action takes place. Furthermore, symmetric interaction implies the notion of reciprocal interactions. This means that an outcome of an action in one environment can be reverted by a corresponding action in another environment. The user experience of symmetric interactions has the potential to further support the impression for users of hybrid environment to act in *one* environment or world. The research in hybrid symmetric interaction relies on the capability of smart environments to reconfigure physical spaces according to changes in a virtual world and vice versa. A framework that implements symmetric interaction will enable users to seamlessly use both the real and the virtual world to accomplish planning, scheduling and surveillance tasks.

3.5 R4 - Space-Time Dispersed Interfaces

The humane city requires the exploration of novel user interfaces that might be dispersed not only in space, but also in time. Similar to the well explored space/time matrix established in the area of Computer Supported Collaborative Work (CSCW), this research focuses on different ways humans can interact in time and space through and with computing machinery. While the space dimension in the space/time-matrix is differentiating between “same place” and “different place”, the humane city requires taking into account meaningful geographic scales for inhabitants. Depending on the social context of living, different interaction options might be applicable. If citizens are moving through the city, these options need to be changed on the fly, not only absolute geographical space matters. Individuals define their own relative spatial frame of reference, which need to be accessible by services. Information should follow users along their trajectory through space, for example by being presented on displays along the citizen’s path. If dynamic information is presented this distribution of information should also be scheduled not only in space, but also in time.

To realize this vision, dynamic scheduling concepts need to be developed which distributed content and interaction possibilities through a space-time continuum of computing machinery on a city wide-scale.

Another interesting research question is to identify meaningful city scales, which would require interfaces to support communities. For example interaction with neighbourhood interfaces (such as public displays installed at central landmarks in a neighbourhood) may be considerably different from interfaces to city-wide information systems (e.g. ambient information systems that indicate the energy consumption of the city as a whole, through the light temperature of the city's public illumination). Also interesting is to investigate the time persistence of different city interfaces which support social interaction. These might last for a long time (e.g., for helping to keep a historical record of city events) or be very volatile (e.g., when supporting a spontaneous interaction of two individuals meeting in a space).

3.6 R5 - Crowd and Swarm Based Interaction

Traditional Human Computer Interaction research is primarily concerned with individuals interacting with computers and with the environment. The research community of Computer Supported Collaborative Work (CSCW) addresses the issue of supporting groups of individuals collaborating on tasks. This group collaboration might be co-located or distributed over several sites, and interactions might happen concurrently or asynchronously. However, most of this research has been focused on small group interaction (less than ten users) and not large crowds (hundreds or thousands of users). Recent developments in social software applications show how larger groups of users can interact and communicate together through internet-based applications. However, the synchronous and spontaneous interaction of larger groups has just begun to be addressed in simple applications, such as SMS-based voting systems, GPS-based urban games, or artistic exhibits. There is a significant amount of work to be undertaken on how technology can be used to support crowd interaction.

The particular focus of this research line is to investigate the role of smart urban spaces in supporting large group interactions. The basic characteristics of large groups or "crowds" are that they consist of hundreds or thousands of individuals and are considered to be at the same place. The individuals of the crowd are engaged in similar activities and are collocated rather than distributed, e.g., the audience to a football game. As a result, there are a myriad of possible concurrent and real-time interactions that the crowd can engage in. Complex behaviour emerges and dynamic social interactions similar to those of swarms can take place. Therefore, the goal for this research is to envision new forms of interaction that accommodate crowds in urban spaces.

Conceivable scenarios for crowd interactions include sporting events, public festivals and city transportation. For example, in large sport stadiums fans already act together, singing, giving applause as well as forming the "Mexican Wave" The large display walls in stadiums allow for new forms of feedback for crowd interactions based on personal devices and various sensors. Commuters in public transport and private cars (particularly in traffic jams) could form a crowd that spontaneously and implicitly interacts with each other and with their environment. Furthermore, it has been shown how cell phones can be used to monitor large scale crowd movements. This could be used to influence traffic light sequences on heavily used roads for optimising throughput. Social relations in the commuting crowd can be discovered and established on the daily travel into the office for entertainment and leisure purposes. In these scenarios, the research in crowd and swarm interaction builds upon the interplay between emerging complex social behaviour and new communication capabilities provided by smart urban spaces and personal devices.

In this research field, there are many possible important topics, including:

- How can crowd based interactions be simulated?
- How can crowd based interactions be evaluated?
- What social theories can be used to predict the impact of technology on crowds?
- How can personal devices be used to support crowd based interactions?

3.7 R6: Spatial and Embodied Smartness - Smart Spaces as Distributed Cognitive Systems

3.7.1 Smart space as outside-in robot

A smart space is - at the most general level - a physical agent that acquires data from its environment through sensors and acts upon this environment by way of actuators. The characteristic property of a smart space that distinguishes it from other kinds of physical agents is that both its perception and actuation capabilities are limited to the inside of a bounded & connected space, and that it integrates a relevant model of this space upon which the interpretation of its sensor data will be based.

The agency of a smart space may correspond to various degrees of "smartness" on top of these basic model-based perception capabilities: it may be pre-programmed for simple "reflex" actions, goal-directed, maximize a utility function or have learning capabilities, etc., qualifying it in a more or less proper sense as a full-fledged cognitive system.
These cognitive capabilities are embodied in a sense that may be less obvious than is the case for a classical robot, but may still correspond to the strict definition of embodied cognition: it is based on an action-perception loop and the physical nature of the corresponding sensory and motor skills does both bound and ground this cognition. Embodiment is thus not based on the zoomorphic notion of a "body", but on the existence of feedback loops through the environment.
Most of the sensors and actuators of a classical robot operate towards the outside of the robot, whereas those of a smart space operate towards its inside. A smart space could thus be considered as an "outside-in" robot.
From the system's viewpoint, the human user is an element of the environment of a smart space and is, as such, sensed and acted upon by the space.
From the point of view of the user, the smart space is a unified interface that subsumes all the traditional individual interfaces of the devices that make up the smart space: they are operated jointly and offer their input and output capabilities jointly.

3.7.2 Multi-scale/-nested smart spaces: smart surfaces, skins and buildings as smart interfaces

As smart spaces scale up, they may also comprise nested smart spaces (e.g., a smart building may comprise several smart apartments, which, in their turn, may comprise several smart rooms).

In this context, an emerging research issue is achieving seamless "smartness" among heterogeneous smart spaces of different scale. As an illustrative example, imagine a person moving from an apartment to another one in the same building, then from the building to the street and then into another building. Although all these spaces will probably comprise different technological infrastructures, this person should ideally experience the same level or type of "smartness" without any discrepancies or problems. In other words, in order for a city to be considered as "smart", it should be able to exhibit ubiquitous and homogenous "smartness" and not just an arbitrary collection of assorted smart spaces.

The idea of considering the smart space as an outside-in robot applies mainly to the lowest scale of a smart space, environments, e.g., a room or a home. But when smart spaces are nested and we move towards bigger and more complex entities, such as buildings, blocks of buildings, neighbourhoods, or entire cities, then sensors and actuators are distributed on both in the inner and outer surfaces of the smart space, allowing it to sense and affect both its inner and outer environment. Furthermore, a smart building will not only comprise sensors and actuators, but also other smart entities (rooms, flats, public areas), some of which may work as "black boxes", exposing a limited communication interface towards the building, while others may allow for low-level, fine-grained, introspection and control.

3.8 R7 - Awareness and Feedback Technologies

Awareness and feedback technologies for Humane Cities encompass all the technical solutions that contribute to a high degree of coupling between the human users and their environments. Stronger coupling is made possible through the mutual knowledge of the internal status of the different parts of a coupled system as well as through a rich representation of the context. Human computer interaction has been historically based on a communication paradigm, centred on intentional and explicit interaction triggered by the user, and with a reduced knowledge of the user's psychological and cognitive status from the part of the computing system. New approaches like affective computing or the consideration for the emotional dimensions of the interaction have started to address the experiential and less explicit dimensions of interaction in a different way. The Humane City vision also builds on the ubiquitous and disappearing computer perspective. In this context, the experiential and implicit nature of the interaction becomes even more relevant, and the opportunities for natural and device-less interaction should be developed.

Awareness and feedback technologies (AFT's) are able to infer psychological, cognitive, and social states of individuals and groups (some examples are attention, stress, anxiety, relaxation or concentration), take those states into account, and provide feedback (positive or negative), to the individual or collective users. This perception capability is grounded on sensing technologies and systems, based on concrete physical sensors – like physiological measures of individual users (electrocardiogram, electroencephalogram, electromyogram, …), or on indirect signal capture and processing techniques (gaze detection, voice analysis, facial expression recognition, body posture analysis). The actual feature detection and classification depends on operative models adopted for each state, which are situation and context-dependent. The same situational nature applies to the design of the feedback mechanisms.

Awareness and feedback technologies for Humane Cities should cover a wide spectrum of situations, from specific individuals in very well defined tasks (as in Assistive Technologies), to less defined individuals in loosely coupled activities (public spaces), groups in multiple contexts, or very large groups in concentrated or dispersed situations. While the notion of collective emotions or cognitive states like anxiety or attention is surely operationally different from their counterparts as defined for an individual, these broad properties should be understood and harnessed in the scope of systems for Humane Cities.

Social information like the demographic characteristics of the human users involved in interaction situations communicators (age, gender, race, socio-economic status, residence) as well as contextualized personal characteristics like accent and/or tone of voice, mood, facial movements, size, gestures and attitudes, should be considered for effective interaction design. Complementary to the human-related features, Awareness and Feedback technologies for Humane Cities integrate environmental features, again in the broad sense. Ambient temperature, noise, lightning conditions, humidity, atmospheric data, or even physical or chemical characteristics (e.g. olfactory information) should be integrated with the adequate sensing technologies and contribute to the experience design, based on a rich feedback loop between environment and users.

Technologically, the creation of effective Awareness and Feedback features in Humane City environments is based on very large numbers of "invisible" and “embedded” small computing devices, interacting simultaneously and being used by multiple users in a wide range of dynamically changing situations. This requires infrastructures for device intercommunication, functional co-ordination, and intelligent scheduling of information and tasks in a self-organizing manner. Humane City systems understand social signalling and social context, based on the improvement of collective decision making integrating all types of users, local and remote, individual and collective. Feedback has to be limited and kept under user control. A sensor-enriched environment may also become a “sensor-polluted” environment where the user is overwhelmed with the amount of generated feedback.

The *research challenges and requirements for awareness and feedback technologies* can therefore be summarized as:

- Keep humans in the loop in all possible life situations and facilitate them with options for informed action and mature decision-making by moving away from fully automated systems and promoting people-orientedness and empowered smartness.
- Design and build computing infrastructures that enable intercommunication of a wide range of devices, sensors, actuators and a functional coordination and intelligent scheduling in a self-organizing fashion.

3.9 R8 – Emotion Processing

Technological advances in microprocessor-, communication- and sensor-/actuator systems, miniaturization and global networking have enabled and created ICT systems that mostly engage visual and auditory human perception, while leaving out or even ignoring the affective subtleties inherent in any kind of human experience: emotions. While Pervasive Computing and Ambient Intelligence Systems have created and continue to create technology-rich environments to deliver one or the other service for humans when working, learning, communicating, socializing, to literally every aspect of human life, it has failed in addressing the very nature of human beings, namely their affective behaviour. To phrase it with the maxim of Ubiquitous Computing: it is the complex interplay of visual, auditory, but also tactile, olfactory and gustatory perception, combined with the instant recall of memorized experience, emotions, that are “woven into the fabric of everyday life”. An ICT ignoring emotions as the fabric of everyday doing, communicating, interacting, sharing, learning, planning, guiding, decision making, experiencing, -be it for whatever reason (technological, organizational, perceptual, etc.)- is poor and “in-humane”.

Attempting for an "emotional ICT" by allowing for, or integrating means for emotional expression into technology appears naive (e.g. explicit emotional expression via emoticons in email communication, facial cues in video conferencing, vibrotactile clothing, etc.). "Emotional ICT" to appear humane must be rooted on clear concepts of understanding about and adequate models for human feelings, the very nature of their cause, raise, appearance and expression, the diagnosis of their presence and their recognition with technological means (seemingly way beyond mathematical pattern analysis of fused multi sensor streams), their representation in abstract data models, their storage and retrieval, their distribution and delivery over data networks, and the technological systems able to generate patterns of stimuli reproducing them – even in inter-subject contexts. What comes, is being expressed and being perceived naturally in almost any human life situation, individually, in conversation or interaction with others, in groups or crowds, in homes, offices, public places or cities, what is being expressed implicitly or attentively, totally lacks any technological handle as for today. The technological approach of sensing, recognizing, collecting, representing, distributing and generating or recalling emotions is referred to as "emotion processing" here.

A "theory of technological emotion processing" as the foundational basis for "emotional ICT" is – as opposed to theories grounded on rationality and built on top of mathematics – due to the irrational nature of emotions way beyond the methodological apparatus of engineers ("wishful thinking" in common parlance), and is seemingly way beyond the capabilities of contemporary information sensing, processing, storage and communication technologies. Moreover, the irrational nature of emotions, their modulation with 'subjective' experiences, the perspective relativity attending different points of view, the lack of objectivity of value (take beliefs or desires as an example), the non-ordinal, non-metric scales of value (like "reasonable", "appropriate") preventing from an independent assessment, etc., even suggest that such a theory cannot exist.

Research towards "Emotion Processing" in at least an approximate abstraction of the principles of how humans perceive, experience and act emotionally, however, faces potential for a whole new epoch of Ambient Intelligence Systems not only being sensitive, adaptive and responsive to the users capabilities, needs, habits, but also to his desires, empathy and denial. In the first place, research questions could address the mechanisms of sensing, recognizing and representing emotional state, together with the modelling, abstracting and representing experience. Furthermore, the mechanisms of deriving (rational) effective action from the confluence of sensory perception and experience, as well as the learning from stimulus-response cycles and their representation in appropriate models. Last, but not at least, the compendium of research questions that relates to the communication and sharing of emotions, involving the capturing, interpretation, transmission and stimulation of emotion in human-to-human interactions.

Some crucial aspects of "Emotion Processing", in particular, have a compelling claim to radically change ICT solutions: (a) emotional experience sharing, i.e. enabling ICT mediated human-to-human emotional expression over distances (see the "Hug Shirt" as an early concept), and (b) the evolution of emotional digital artefacts, i.e. the ICT implemented emotional behaviour of electronic devices (computers, tools, machines, appliances, objects of everyday use, environments, spaces, etc.) in machine-to-human emotional expression (see emotional humanoid robots as an early concepts), and (c) emotional adaptivity in human-to-machine emotional expression, i.e. the emotional state recognition of humans based on sensed behaviour and the provision of services in a way respecting emotional states.

3.10 R9 - Social Networks and Collective Intelligence

Social relations and networks deeply influence everyday experiences in global cities. For the first time in history, people are able to use technology to allow them to connect to global virtual social networks from their physical urban locations. This enables social networks to extend beyond physical boundaries and creates large networks of collective intelligence. However, today's computer systems are not fully aware of social networks in a city, and unable to effectively support various urban activities. This is because of a lack of sensor data providing important cues for supporting social networking and collective intelligence.

Technologies such as GPS can capture people's location and their mutual proximity and this can be complimented by other kinds of sensors that reveal body orientation, gaze direction, and eye contact as well as visual, auditory, olfactory and thermal experiences. This data together could allow for more accurate estimation and richer understanding of social networks, thereby facilitating the development of socially aware systems. Such systems could support meaningful encounters by recommending relevant people, places, and things, and facilitating interactions with strangers as well. Consequently, they could positively impact social creativity and collective intelligence of ad-hoc urban social networks.

In this research line, there are a number of topics that should be explored, including:

- social networking tools for creating collective intelligence
- methods for evaluating collective intelligence
- what is the role of communications networks in creating collective intelligence
- collaboration tools for collective intelligence and decision making
- understanding the impact of collective intelligence on urban life

3.11 R10 – Self-organization in Socially Aware Ambient Systems

Different paradigms will dominate the future of information and communication technology. These systems will be more and more distributed and will consist of numerous networked devices of different scale, resources and capabilities. Consequently, services and functions have to be composed ad-hoc in a self-organized fashion and adapted with respect to limited resources, but also adapted to local and global situations and/or environmental needs. Information will and has to become pervasive as well persistently available and the corresponding information services have to become adaptive with respect to the user needs in the long term.

Already at this stage, people are used to share content with other users, resp. to consume content that is made available by others. Thus, in principle, ad-hoc communities of P2P-device environments exist that are joined for very short term. But the major feature of today's applications is the time-shifted consumption and production of content and services that is controlled by a centralized application, where all users must be connected to.

Beyond the general research challenges and requirements listed before, we add here now the challenges from a technical point of view that has to be solved when creating ambient computing and communication environments using a multiplicity of devices:

- Establishing self-organization of a multiplicity of resource-limited devices (e.g., personal devices like mobile phones, PDAs etc. that are restricted in energy and processing power) within permanently changing device and environment conditions:
    - at the system/service level for guaranteeing communication and cooperation with respect to rapidly changing topology conditions
    - at the semantic level for guaranteeing service reliability and configurability of content with respect to rapidly changing sets of service providers and service consumers

- Establishing self-organization of a multiplicity of service providers and consumers with respect to content delivery reliability by guaranteeing
    - Context-sensitive service delivery in a self-learning and self-adaptive manner with regard to the needs of changing user groups and changing individual user needs and their individual environment conditions
    - Real-time service provision and service access

- Establishing configuration tools for adaptation of device ensemble behaviour within rapidly changing device environments and device conditions. This will:
    - provide added value for telecommunication providers by maintaining the potential to configure the overall behaviour of users' p2p devices
    - increase customer loyalty by making highly innovative and interactive service delivery accessible by the users

3.12 R11 - Realization and User Experience of Privacy and Trust

This research line has its origin in the conflict of *data provision vs. control and human attention*. The resulting issues of privacy, trust, identity, etc. raise not only technical challenges but also social and ethical issues, especially when considering the legal and moral rights that are the basis of the constitutions of today's democracies.
Privacy is a complex of information and social restrictions on access to a person or group. It includes limiting when and who can make what information and attention request of a person or persons. Privacy, secrecy, security all relate to each other but are different.
The role of Ambient Intelligence for privacy concerns many themes of what information is valuable to secure from whom when and how that can be done. In this effort, social sciences research will augment the known cryptographic approaches to security.

Due the complexity of the issues, we list a number of questions and discuss them in such a way that - as a result - a wide range of future research activities are being triggered.

Will limiting recording be part of improving privacy?
Sensor and history data is making all activities on the earth identifiable and recordable. Typical notions of privacy hold that there are times to record and not to record. As it becomes more difficult to stop recording what can be done to protect ourselves. A set of work

concerning eliminating recording devices has been ongoing. First the US military and then some European communities are calling for Google to stop creating Streetview recordings. When residents or tourists look at everything on a street it is less of an intrusion than anyone that is not physically present to be able to view it. Research concerning approaches to limiting recording and auditing such limitations is essential to understanding the value of attempting to limit recording.

Are there ways keeping the information contained?

When information is recorded, there are technical policy and legal approaches to protecting it and people. We have seen how an image of a famous athlete smoking marijuana at a party could be recorded by a cell phone and posted immediately challenging his reputation and livelihood. Research on the ethics and technology of containing technology will help guide technology development, policy and case law.

Will destroying data improve privacy?

Are there new notions of sharing information that will emerge? Securing devices can and will reduce information flow and sharing. No physical or computational securing approach except extinguishment is eternal. Research concerning when and how data might be extinguished and how to verify their extinguishment will help to define future limitations to privacy.
Many legal and accounting firms hold themselves to strict rules, never sharing information about their clients to people not on those projects. They destroy all electronic and physical records at the end of any engagement. Such an approach stands in stark contrast to the scientific community metaphor that states it as troublesome for any piece of data or experience to be ever lost. Scientists consider it a great value of publishing retractions instead of deleting old, wrong theories (such as Newtonian mechanics in the face of relativistic mechanics). The research concerning privacy then will wrestle with the philosophical: should all sensor systems keep all data archival? To the extent that they do, we can revisit a corner where a crime happened and test people's claims of being there or not. To the extent we do, not only are we "violating" the privacy of everyone in the pictures but we are creating a new world; a world where history will and can be discovered with new questions revisiting historical sensor nets again and again. Research is needed to understand the consequences of a more explicit policy that privacy will not mean exemption over time from knowledge of actions.

The facts of privacy will ride on policies of access use and reuse of ambient sensor data as we go forward. Understanding policy of protection of facts will be deeply controversial. Should your current wife be able to visit the home you had with your previous wife. Should your previous wife be able to visit the sensor data of your previous mistress? How and who will have access to ambient sensor data when? After I die, do I allow my children or countrymen discover the secrets of state I worked on? Research concerning ambient intelligence might contemplate creating new structures for securely changing privacy rights.

Can all knowing security agents help us keep our privacy?

Imagine we used to all live in the open. We might sit around a fire place; we could watch each other doing everything. There was community. As some went off behind the bushes to have a bit of separateness we could call privacy. But what of the people going off to see if people at the fire acted differently when no one was watching them. Such surveillance activities are part of the prey and the predator stance as well. In fact dogs co-developed with people. These dogs guarded the people as they worked, played and slept tirelessly watching and listening and signalling unfamiliar and dangerous activities that required action. These dogs are in a very real way the pervasive sensors which ensure safety and security. Is the fact that they don't talk to their master or others part of what gives their masters privacy? How can the user models of an ambient intelligent system be queried: can they be difficult to read by others like a person's dog, or completely public? A line of research concerning robotic guards can help us understand the role that active security might take in our evolving privacy models.

How are security and privacy intertwined?

Soon people moved their fire inside a cave or small hut to get privacy and safety. At first it may have seemed perfect but the dogs sniffed the perimeter when people came home: was there a predator hiding; was someone going to trap us in the cave? Separate from security a line of research must explore the relation of privacy and safety. Indeed we look at a cat crunched up in a corner with one eye almost closed: do we have privacy around him? No one has privacy around a cat but power dominance allows many of them to have safety. Privacy as a social concept is part of an even larger social concept. The cat's awareness of us and our awareness of its awareness does give us a sense of community. The dog with respect to privacy is different. If the dog is locked somewhere it must be out of hearing range for us to feel a sense of privacy from the dog. On the other hand when associated with us they maintain privacy even as we walk through dangerous neighbourhoods and near people we are worried about. Research evaluating the relationship between privacy and security in sensor-rich environments will help guide business and policy necessities.

Which new notions of privacy will have to be defined?

Today the internet is a new non-private place. As we create private places to get away from the non-private internet we will obviously lose some of the interesting experiences and conversations that allow anyone to participate.
How will the new privacy offer the ability

- to do things without others interfering?
- to limit social experiences?
- to be selective about who we associate with when?
- to keep information relative to a variety of relationships separate from each other for ever?
- to keep secrets at all?

Research on privacy must include evaluation of the goals and consequences of new definitions of privacy.

Physical systems are changed by the fact of observation. This is not true with digital communication which can be broadcasted with complete fidelity indefinitely.
One challenge is that so much of the technology of knowing what others are doing is non-symmetric; we can technically be observed without knowledge that we are being observed.
Privacy policy might create the new physics of sensing in which, as in the physical world, sensing requires indelible records, or it might respect the physical world by not adding indelible digital records just because something happened. This crucial line of research must explore approaches to limit the spread of a person's information to socially uncalled for places and for socially malevolent goals.

As we come up with approaches and definitions we start with our needs. We might want privacy from people in parts of our family or social network for some parts of our activities. We might want to expose ourselves to anyone when lonely and hide from everyone when trying to concentrate. We might be especially interested or uninterested in people very different from us. We will have to define privacy as stable information within the groups that have the privacy from others. When the information being stably kept from people outside those groups is incorrectly transmitted to them, we have breached the privacy. Research is needed concerning how such groups should be defined. How do we present such barriers so as to be archival?

What is the relationship of Privacy and Security technologies?

While research that reaches across anthropology, computer science and political science to develop the alternatives for privacy, classical computer security research will certainly be applied to ambient intelligence data as well. In adapting and integrating cryptographic security technology to AmI, new opportunities will also be available. The opportunity and value of multiple different sources and repositories in n-version or byzantine security and programming should be studied and understood. Such research shows how separate and diverse sources of information can help control information and productively inform many other security and reliability discussions as well.

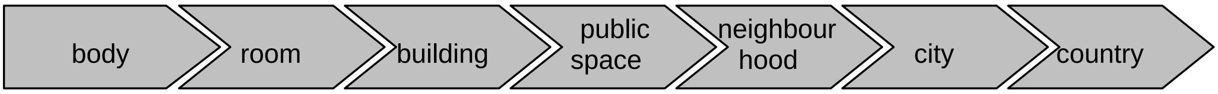
Privacy standards have already made a deep impact on the requirements of sensors used in public places. Security cameras are required to be shown to not record information for property not under the jurisdiction of the owner of the cameras. They do this by mechanically or electronically vigneting the edges of its area of sensitivity. White noise generators are commonly used by therapists, executives and human resource people to keep others from eves dropping on sensitive conversations to improve privacy. The Babble system from Herman Miller is designed to mask conversations by with the actual sound of the voice of the person who is talking.

As research projects are defined to define privacy in an ambient intelligent world, there will be a long list of knowledge types to consider one at a time.
What opportunities and privacy technology are emerging for

- wireless transmission of knowledge?
- wired transmission of knowledge?
- time value of privacy of data?
- actively acquired knowledge about places activities and people?
- optional sensing for people who are currently able bodied?
- required sensing for sustaining people with special needs?
- medical and medical records?
- passively acquired knowledge about places activities and people?
- sensing that can be noticed and versus not noticed versus clandestine sensing?
- sexual, violent and illegal activities?
- dangerous mechanical, electrical, chemical and biological activities?
- identification / tracking. What follows RFID?
- personalized data tracking?
- continuously tracking of people / objects?

3.13 R12 - The Scaling Issue

The Ambient Intelligence paradigm has to deliver extended support to all users, seamlessly throughout the living spaces meeting their needs and preferences. Ambient spaces are physical places featured with AmI-enabling technologies, including the intelligence supporting the services. The scaling factor can range in the following way:



And it can grow more depending on how complex it will get due to the huge amount of functionalities it will provide:

The ***body*** of the user is the closest environment that includes sensors and actuators, usually embedded in garments and personal objects communicating via a Body Area Network (BAN).

Buildings and the ***rooms*** constituting them are the places where most of the services take place. These spaces are equipped with innovative technology of sensors, actuators, interfaces, middleware and knowledge based systems communicating through short range wireless communication networks (currently ZigBee, Bluetooth, W-LAN).

Public spaces and the ***neighbourhood*** is where people usually go and is the natural extension of the building to provide the continuity of attention and service, enabling social inclusion while preserving safety and protection. Usually the neighbourhood is constituted by enabled in-doors and out-doors spaces like a park and public gardens, the day centre, the pharmacy, the supermarket, the City Hall, and others.

The ***city***: the town covers all its inhabitants and visitors with its urban life management as described in the umbrella scenario of the Humane City.

The ***country*** is where the political decision and practical actions are being taken to enable the building of a global environment. Here, we have to consider the expression of emotions regarding different cultural background of the users.

The scaling of AmI-spaces is not a straightforward or a trivial task. Quite a range of problems arise when moving beyond the more or less well-defined and constrained realm of personal spaces, such as rooms, flats and homes. Some of the related problems include:

Fuzziness of smart space boundaries

When one refers to a smart room, home or building, the related spatial boundaries are universally well-defined. Thus, it is quite easy and straightforward to identify the AmI technologies involved as well as their "users", related interactions, activities, etc. On the contrary, notions such as neighbourhood, city, metropolitan area, etc. are geographical terms with loose physical definition, which often have a highly subjective meaning. For example, the region that I conceive as "my neighbourhood" may be totally different than the one considered by another person still living next-door. Furthermore, some of these areas may overlap (e.g., adjacent neighbourhoods may share some spaces), or even dynamically change over time (e.g., on certain seasons some indoor spaces may be extended to include outdoors spaces, and during rush hours the definition of the "city centre" may expand). Thus, a related emerging research issue has to do with defining and creating AmI environments with fuzzy and dynamically changing boundaries.

Conflicts of interest among AmI-spaces

Up to now, AmI-environments are mostly considered as "single-minded" entities with well-defined, homogeneous and coherent goals, e.g., a smart home that caters for the safety and well-being of its inhabitants. This might be true for smaller – and mainly personal – spaces. However, in a smart city comprising a very large number of AmI environments of different scale, such an approach is not realistic or viable. As we move from smaller to larger spaces, the number of people and AmI-resources residing in them increases, and people do not always have common goals or intentions. In addition, it is very likely that different AmI-environments will also have different goals. This means that conflicts will inevitably arise.

As a result, a smart city cannot be considered as a scaled up model of a smart room or a home, but rather as an ecosystem of (possibly) antagonistic AmI environments striving for survival, or even predominance. Some of them may select to achieve this through negotiation and collaboration with the rest, while others may follow more aggressive and less politically correct approaches. In this context, a predominant research issue is creating AmI environments with social skills and behaviour, which are not only targeted towards their human inhabitants, but also to other co-existing AmI environments.

Availability, ownership and use of resources

Large AmI spaces will require large numbers of related technological resources. Some of them will be private (e.g., the body area networks or those installed in homes or buildings), while some others will be public (e.g., those in the streets, or public areas, cities or countries). Since a smart city will comprise several types of interleaved AmI environments of different size and scope, there will be a need for some kind of seamless "integration" among private and public resources. Additionally, no matter what the number or capabilities of these resources are, it is quite certain that in several cases they will not suffice to meet all concurrent demands.

When considering the above, a number of related questions arise, such as:

- Who will control the use of various resources and how?
    - e.g., if there is a power shortage to the smart city:
      - will the city "itself" be able to instruct (or force?) all AmI resources to lower their power demands?
      - will it be able to selectively shut down non-critical, but private, resources (e.g., electronic advertising billboards)?
- Who will have access to them?
    - e.g., will citizens be able to access public-domain resources for their own benefit?
- How will AmI services be able to allocate and use specific resources that they do not own?
    - e.g., a helper application supporting a blind person to move in a city may need to play a speech message on a public speaker, interrogate the traffic light for its current state, and control the elevator in a private building.
- How will the whole infrastructure be maintained, updated and or extended?

- How will personalized services be offered by requiring personalized interpretation of data:
    - e.g., who is in charge of configuring interpretation rules? Who is in charge of offering individualized services? Which types of situations are triggers for data inspection and interpretation? Who is the receiver of interpretation processes?

In order to get satisfying answers to those research challenges, they have to be embedded and seen in context of a variety of different application areas. While taking urban life management in today's and future cities as the umbrella scenario for creating "humane cities", we have to tackle subsets of this overall theme as, e.g., smart transportation, health care with extensions to ambient assisted living (with a large number of very privacy-sensitive data), responsible citizenship (with interesting aspects of cultural differences and different social contexts).

4 Cross-Thematic Group Synergies

Due to InterLink's structure consisting of three working groups, we are also looking at the overlap of themes with the other two groups: WG1 and WG3. Although they conduct also their own thematic workshops, we list some of the topics that are candidates for cooperation and cross-fertilization.

4.1 WG1: Software Intensive Systems and New Computing Paradigms

The complexity and scaling issues of AmI-environments require new computing paradigms and software layers that facilitate the communication between the human-environment (physical) interaction and the underlying infrastructure. The complexity of the ambient computing world also increases dramatically when devices and components originating from differing application contexts must suddenly start to work together. Thus in the next decades large numbers of software-intensive systems will be developed and deployed. These systems will not only feature massive numbers of nodes per system, they will also have to operate in open, non-deterministic environments in which they interact with humans or other software-intensive systems and adapt to new requirements, technologies or environments without redeployment. This future generation of software-intensive systems could be called as ensembles. These ensembles need a distributed software infrastructure that allows a dynamic orchestration of devices and realizes self-organized communication and cooperation of autonomous device entities. Future software-intensive systems are therefore essentially necessary to build up the basis for ambient computing and communication environments and have to achieve following requirements:

- **Composability:** These software intensive systems have to provide a framework that supports the smooth integration and reuse of independently developed components is needed in order to increase the level of abstraction in the design process.
- **Dependability and security:** The provision of a generic framework that supports safe, secure, maintainable, reliable and timely system services despite the accidental failure of system components and the activity of malicious intruders is essential.
- **High-performance embedded computing:** for scalable multiprocessor computing architectures and systems incorporating heterogeneous networked and reconfigurable components. The increase by several orders of magnitude of computing densities will

be key for achieving the topic of WG2 Ambient Computing and Communication Environments.

- **Interfacing to the environment:** new ways of interfacing with the natural and the man-made environments, and in particular more intuitive ways for humans to interact with the technical systems.

With such a future generation of software-intensive systems ensembles could be build up to realize the vision of a city where people enjoy everyday life and work, have multiple opportunities to exploit their human potential and lead a creative life.

4.2 WG3: Intelligent and Cognitive Systems

The increasing “physicality” and hybrid nature (e.g., via augmented reality) of ambient environments implies a strong relationship to WG3. Topics of common interest are especially in the area of sensors and actuators as well as energy efficiency issues. Furthermore, it will not only be useful but necessary to draw on the experience that WG3 researchers have in the area of AI methods and, in general, exploit the body of research and results that exists in the artificial intelligence domain.

A variety of research projects in the area of ubiquitous/pervasive computing have produced fundamental results. However, from an architectural point of view, today there exist only isolated point solutions for rather constrained scenarios but no holistic solution that would allow the integration of sensor-actor systems, devices with widely differing capabilities and a wide variety of services provided by the infrastructure into dynamically reconfigurable ensembles to support the user’s needs across multiple domains. While the need and market potential for ambient computing and communication environments is clear, there is currently a lack of marketable products that significantly rise above purely isolated applications. Viable, innovative services remain on our wish list, a distant, albeit desirable dream. Some of the isolated applications currently available include home emergency systems, which are constructed as pure alert signalers, sensors for light control, or device-specific user interfaces. These applications could only be linked together with a great deal of effort, with any emergent alterations requiring the involvement and expertise of system specialists, thereby increasing solution costs considerably. In addition, sensors and other hardware components, as well as individual functionalities, have a tendency to require multiple installations with multiple associated costs, as the systems are only offered as complete packages, data exchange formats and protocols are not compatible, and components from one application cannot be used by another application. Likewise until now, it is impossible to generate higher value functionalities through combining layers of individual functions.

Additionally there is a lack of functionality from the different components to realize the goal of an ambient computing and communication environment:

The *sensors* in such sensor-actor systems have to go beyond simple identification of objects from today (RFID-tags). Sensor nodes have to know the local and global positioning and their integration in large scale networks. They should be aware of their absolute and relative proximity.

Actuators are frequently used as mechanisms to introduce motion, or to clamp an object so as to prevent motion. They are devices which transform an input signal into motion. For our Hybrid City approach with a real city with its physical entities and real inhabitants and a parallel virtual city the reaction/motion in future applications the real world could be triggered by an events/actions in the virtual world or the mediated reaction in the real world is triggered by (human) actions in the real world. Additionally in this real-virtual continuum the "robots" could be understand as physical "avatars" of digital actors in the virtual world.

Physical activity will be one important aspect in user behavior analysis. Abnormal movement behavior might be an indicator for an inappropriate lifestyle, insufficient social inclusion, or generally disadvantageous life conditions which might call for medical treatment. Activity tracking / monitoring can make use of information on the physical activity of e.g. residents of a nursing home or elderly patients living alone at home. Thus, it will be also essential that intelligent and cognitive systems allow the use of technology for identifying movement behavior and tracking of activity in everyday life.

Most often understanding of people about context awareness is limited to personal applications. The future perspective on context awareness from the network point of view are wireless sensor networks that offer powerful capabilities to locally and collaboratively sense both personal and environmental data, reason and interpret collected data, and react to various situations. These features bring another level of awareness in the network, which, on the one hand, reduce the amount of communication to the central server and thus increase the responsiveness, and, on the other hand, improve the energy efficiency and realize an *effective energy / power / resource management*. With this knowledge in mind a precise control of the environmental conditions is possible. Examples of parameters that could be monitored include temperature, humidity, light and other conditions. The sensor nodes attached to the environment can automatically form an ad-hoc wireless sensor network to observe and check a set of parameters against some predefined conditions. As soon as these conditions are not met, the nodes can take action and correct the environmental conditions.

In the area of "Intelligent and Cognitive Systems" as well as in the area of "Ambient Computing and Communication Environments" we are confronted with very large numbers of distributed and partially embedded objects and a large number of processors embedded into those artefacts around us. For *sustainability and maintenance issues* they should be able to receive and transmit information concerning their state and behaviour. This is especially essential in case of inaccessible locations. Here the advancement in web technologies allows the remotely located intelligent objects to be programmed, operated, and monitored for maintenance. Remotely located maintenance personnel could watch the status of each object. This capability provides less delay in repair due to unexpected breakdowns or changing requirements, while reducing the cost of unnecessary or premature maintenance.

Real ad-hoc cooperation of distributed device ensembles is obligatory to support self-organization of its components. *Autonomous artefacts and ensembles of self-organizing artefacts* means that the independence of the ensembles' components is ensured, that the ensemble is dynamically extensible by new components and that real distributed implementation is possible.

Seamless connectivity for intelligent systems is not only constrained by communication and computation resources but also by the environment with dynamic characteristics. In case of dynamic scenarios, where people come together in an ad-hoc manner, where each of the users brings his/her own personal devices, or where each may be moving, or where people are buying new sensors or devices for extending their existing device ensembles, *dynamic reconfiguration capabilities* are essential.

Ambient intelligence (AmI) deals with a new world of ubiquitous computing devices, where physical environments interact intelligently and unobtrusively with people. These environments should be aware of people's needs, customizing requirements and forecasting behaviors. Research on *Artificial Intelligence (AI) methods and techniques for AmI* aims to include more intelligence in AmI environments, allowing better support for humans and access to the essential knowledge for making better decisions when interacting with these environments.

There will be also an *emergent behavior in collections of interacting artifacts***.** As computers disappear from the scene, become invisible for the user, a new set of issues is created concerning the interaction with such artefacts embedded in everyday objects to have a smooth access to those services. Thus, future interaction forms will essentially shape everyday life as we know it. Interaction concepts for the control of objects in AAL environments will no longer be centrally realized, as is common, for instance, with the PC. Instead, they will be implemented through networks of (computer) nodes that will interpret user commands and distribute them by way of existing communication infrastructures to the end devices that can best realize the task at hand. Multimodal interaction concepts, such as speech and gesture recognition or computer vision, require computationally intensive algorithms, which can only be executed by stationary computers. Should additional intelligent deductions from existing information be required, the temporarily increased computational effort can still be generated quickly enough through distributed computer nodes. Applications of such interaction concepts include speech interfaces, 3-dimensional interactive video interfaces and emotive interfaces for robots.

5 Suggested instruments for international cooperation

In addition to the general InterLink analysis (for the overall analysis see InterLink deliverable D4.4), we propose selected scenarios for fostering trans-national/trans-continental research collaboration in the thematic areas ambient intelligence, novel human-computer interaction, mixed reality, smart spaces and, from an application point of view, future urban environments or even future cities with a holistic viewpoint. The recommendations address scenarios with joint and parallel funding. They focus especially on collaboration opportunities between European partners and non-European partners that seem to be promising based on the interaction and cooperation of the international experts that were invited to the different workshops of Working Group 2 (Ambient Computing and Communication Environments).
Nevertheless, we also like to emphasize that European-centric funding mechanisms for international cooperation within Europe are very useful for contributing to the overall goal. Examples especially relevant for the themes mentioned above are the Artemis Joint Technology Initiative (JTI) on Embedded Computing Systems, the Ambient Assisted Living (AAL) Joint Programme, and the Coordination and Support Actions (CSA) as part of the FP7 funding scheme.

The InterLink workshops were organized by bringing together invited international experts who facilitated intensive small group face-to-face discussions in different formats and subsequent remote elaboration of the results. Participants were selected in such a way that they cover an appropriate spectrum of approaches and backgrounds. Furthermore, the groups' composition was changed during the duration of the project in order to bring in different people with new ideas. The selected projects and research institutions represented a cross-section of the activities relevant for the goals and covered countries that are at the forefront in these areas.

Besides the excellent results in terms of content, the discussions with the international experts at the workshops also helped to identify certain problems for joint research activities. This included different terminologies in different countries, different scopes and objectives of research funding agencies and programs and differences of the role of industry and financial issues.

Direct funding of foreign institutions appears to be problematic. In some cases it is allowed for developing countries under specific conditions, but it can not be adopted as a general mechanism.

On the other hand, the international experts see feasible direct funding possibilities of individual researchers from abroad and in many other countries. The recommendations include exchanging goal-oriented and theme-specific research perspectives in further international workshops that are to be attended by experts, mainly senior researchers. These workshops are meant to identify concrete objectives and to define processes for realization. The next step concerns the implementation. This can be done by scholarships or visiting researchers, who join the foreign institution for a defined time (1-2 years). This is complemented by exchange programs for Ph.D. students and by providing internships for graduate and undergraduate students who acquire practical experiences by working on the realization of specific subprojects.

At another level, we propose week-long annual/bi-annual summer or winter schools on selected topics that consist not only of lectures and discussion but include also hands-on experiences in actually prototyping components (in the community called “Hackfest”).
As a result of the close formal and informal communication and interactions between the workshop participants for two years, we foresee an intensive scientific, technological and even commercial cooperation between Europe and Asia (in particular Japan, Korea, and Singapore) as well as Australia and New Zealand. This does not exclude collaboration with partners in the US but they were this time not at the core of the workshop activities.
These countries are active in developing national plans and activities for supporting their people in a wide range of areas, e.g., transportation, safety, security, health and well-being, but also to facilitate citizen’s involvement in the community, fostering engagement and responsibility. These plans come under different names (e.g., the u-Cities and uT-Society program in Korea, “U-Japan” as a ubiquitous network society, the iN-2015” Masterplan (Intelligent Nation Singapore) and are based on ambient intelligence technologies and approaches. They are open for collaboration wit European partners.

In order to exploit these collaboration opportunities, it is helpful that key players of these activities participated in our InterLink workshops. Their participation resulted in identifying areas of collaboration with the following institutions: Keio University, Japan (Masa Inakage, Adrian Cheok) and IDMI (Interactive Digital Media Institute) at the National University of Singapore (NUS) (Ryohei Nakatsu, Adrian Cheok). In this context, it is important to note that Keio University and NUS have recently created the CUTE research center in Singapore, which funds joint research activities and is open for international collaboration. Other collaboration opportunities opened up with GIST (Gwangju Institute of Science and Technology) in South Korea (Woontack Woo) and the South Korean national UCN project (We-Duke Cho); in New Zealand with the University of Canterbury (Mark Billinghurst) and in Australia with the HxI-Initiative led by CSIRO, DSTO and NICTA (Bruce Thomas). With respect to the collaboration with partners in the commercial area, we identified, e.g., in Japan the C&C Innovation research laboratories of NEC (Keiji Yamada).

Further exploration and clarification of research areas and potential partners are planned, e.g. ideas of FP7 projects where funding options could be investigated through "parallel" funding possibilities. As a result, we will be following up new possible avenues for cooperation, particularly Australian and Asian cooperation in EU projects in the Ambient Intelligence area using a "matching funds" scenario. Still, we have to consider that the funding agencies in different countries might have different objectives, strategies and priorities. There is some funding available for Australian researchers to participate in EU FP7 projects in the AmI area, but they need to be part of the proposal when it is first submitted to the EU for funding.

An additional promising approach would be to use FP7 Coordination and Support Actions which may also involve participation from the international community. This will allow setting up various types of knowledge exchange and sharing initiatives at an international level. In particular, cooperation and support actions can serve the purposes of initially establishing international groups or small communities which can subsequently participate in joint research activities as well as ensuring more internationally visible dissemination channels for joint or parallel research work already conducted.

6 Summary of recommendations

At a basic technology level, we recommend that research in the area of Ambient Computing and Communication Environments should be concerned with working towards the *provision of a computing, communication, sensing and interaction "substrate" for systems and services*. The expected result can be characterized as a "*smart ecosystem*" in order to emphasize the seamless integration of the components, their smooth interaction, the "equilibrium" achieved and the "*emergent smartness*" of the overall environment. We expect that the economics will help such a basic technology to evolve from the currently existing large variety of specialized components into a small number of universal, extremely small and low-cost components that can be embedded in a variety of materials. The resulting "substrate" will allow *to invent and to realize innovative interaction techniques in order to provide a more holistic and intuitive usage and interaction experience* than it is possible today.

Beyond these basic technology-oriented developments, we recommend to *develop a roadmap for future research agendas on the basis of an umbrella scenario* that provides guidance and opportunities for detailing. The *theme of Urban Life Management in Smart Cities* was selected as the starting point. On this basis, the *concept of "The Humane City"* was developed as our vision for the City of the Future and the future of Urban Living. The most important argument for its relevance is that already by the end of 2008, half of the world population lived in urban areas. We have entered an *Urban Age* and the economic prosperity and quality of life will largely depend on the abilities of cities to reach their full potential. Based on the umbrella scenario and the goal "Towards the Humane City: Designing Future Urban

Interaction and Communication Environments", we recommend to support research along the following twelve research lines in the area of Ambient Intelligence:

R1: Rationale for Humane/All-inclusive Cities (users are citizens)

R2: Tangible Interaction and Implicit vs. Explicit Interaction

R3: Hybrid Symmetric Interaction between Real and (multiple) Virtual worlds

R4: Space-Time Dispersed Interfaces

R5: Crowd and Swarm Based Interaction

R6: Spatial and Embodied Smartness (distributed cognitive systems, outside-in robot)

R7: Awareness and Feedback (sensors, physiological, environmental …)

R8: Emotion Processing (affective computing)

R9: Social Networks and Collective Intelligence

R10: Self-Organization in Socially Aware Ambient Systems

R11: Realization and User Experience of Privacy and Trust

R12: Scaling (as the major horizontal issue)

7 Conclusions

Looking back, we can state that the activities of the Working Group 2 "Ambient Computing and Communication Environments" were a very successful endeavor and for us as the chairs of this working group a very satisfying experience. We were successful in having our invitations accepted by a very special group of international experts representing excellence and expertise in a wide range of topics and at the same time diversity of cultural and scientific backgrounds. This made the face-to-face meetings at the workshops and the remote work between the meetings a truly interdisciplinary collaboration and transnational communication process. Carefully changing and extending the composition of the groups at the different workshops while at the same time keeping a core for maintaining continuity helped us to extend the perspective significantly. By going beyond rather basic considerations and standard search for new research topics, we were able to generate a comprehensive umbrella scenario (Urban Life Management) and a demanding vision (Humane City) providing relevance and also a sense of responsibility that guided us in the development of the different research lines for future research agendas in the area of Ambient Intelligence. Because these ideas deserve to be heard by many people, it is our goal now to disseminate our considerations and recommendations as a white paper to a large audience addressing the scientific community and a wide range of funding institutions at national, European and international trans-continental level.

References

(for references relevant for work in this area, we refer to the state-of-the-art report constituting the deliverable D3.2)

ANNEXES

Annex A: List of contributors

Participants and organizers of the four workshops of WG2 "Ambient Computing and Communication Environments"

First Workshop in Eze, France, May 2007

Organizers:
Norbert Streitz (Germany)
Reiner Wichert (Germany)

Participants:
Adrian Cheok (Singapore)
James Crowley (France)
Joëlle Coutaz (France)
Alois Ferscha (Austria)
Lorenz Hilty (Switzerland)
Antonio Krüger (Germany)
Pei-Luen Rau (China)
Ichiro Satoh (Japan)
Bruce Thomas (Australia)
Woontack Woo (Korea)

Second Workshop in Eltville, Germany, November 2007

Organizers:
Norbert Streitz (Germany)
Reiner Wichert (Germany)

Participants:
We-Duke Cho (Korea)
Michael Cohen (Japan)
Peter Eades (Australia)
Dimitris Grammenos (Greece)
Antonio Krüger (Germany)
Gilles Privat (France)
Albrecht Schmidt (Germany)
Manfred Tscheligi (Austria)
Xenophon Zabulis (Greece)

Third Workshop in Tokyo, Japan, June 2008

Organizers:
Norbert Streitz (Germany), Adrian Cheok (Japan/ Singapore), Reiner Wichert (Germany)

Participants:

Tamim Asfour	(Germany)
We-Duke Cho	(Korea)
Anind Dey	(USA)
Alois Ferscha	(Austria)
Dimitris Grammenos	(Greece)
Gaoqi He	(China)
Masa Inakage	(Japan)
Mashiko Inami	(Japan)
Osamu Katai	(Japan)
Shin'ichi Konomi	(Japan)
Ryohei Nakatsu	(Singapore)
Takuichi Nishimura	(Japan)
Rolf Pfeiffer	(Switzerland)
Gilles Privat	(France)
Ichiro Satoh	(Japan)
Itiro Siio	(Japan)
Bruce Thomas	(Australia)
Woontack Woo	(Korea)
Keiji Yamada	(Japan)
Kin Choong Yow	(Singapore)

Forth Workshop in Cannes, France, November 2008

Organizers: Norbert Streitz (Germany) , Reiner Wichert (Germany)

Participants

Mark Billinghurst	(New Zealand)
Adrian Cheok	(Japan/Singapore)
Dimitris Grammenos	(Greece)
Alois Ferscha	(Austria)
Nuno Guimaraes	(Portugal)
Masa Inakage	(Japan)
Suhyun Kim	(Korea)
Antonio Krüger	(Germany)
Seongil Lee	(Korea)
Christian Müller-Tomfelde	(Australia)
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Gilles Privat	(France)
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Annex B: Ethical Issues

There are no ethical issues.