True Visions

The Emergence of Ambient Intelligence

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Into Ambient Intelligence

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"Ambient Intelligence is about everyday technology that makes sense"

1.1 The Vision

Ambient Intelligence (AmI) refers to electronic environments that are sensitive and responsive to the presence of people. The paradigm relates to a vision for digital systems in the years 2010–2020 that was developed in the late 1990s, and which has become quite influential in the development of new concepts for information processing, combining multidisciplinary fields including electrical engineering, computer science, industrial design, user interfaces, and cognitive sciences.

In an AmI world, devices operate collectively using information and intelligence that is hidden in the network connecting the devices. Lighting, sound, vision, domestic appliance, and personal health care products all cooperate seamlessly with one another to improve the total user experience through the support of natural and intuitive user interfaces.

The AmI paradigm provides the basis for new models of technological innovation within a multidimensional society. The essential enabling factor of the AmI vision is provided by the fact that current technological developments will enable the integration of electronics into the environment, thus enabling the actors, i.e., people and object to interact with their environment in a seamless, trustworthy, and natural manner. In addition, the past years reveal a growing interest in the role of information and communication technology to support people's lives, and this not only refers to productivity but also to health care, well-being, leisure, and creativity. A major issue in this respect is given by the growing awareness that novel products such as devices and services should meet elementary user requirements such as usefulness and simplicity. So, it is generally believed that novel technologies should not increase functional complexity, but merely should contribute to the development of *easy to use* and *simple to experience* products. Obviously, this statement has a broad endorsement by a wide community of both designers and engineers, but reality reveals that it is hard to achieve in practise, and that novel approaches, as may be provided by the AmI vision, are needed to make it work.

The notion *ambience* in Ambient Intelligence refers to the environment and reflects the need for an embedding of technology in a way that it becomes nonobtrusively integrated into everyday objects. The notion *intelligence* reflects that the digital surroundings exhibit specific forms of social interaction, i.e., the environments should be able to recognize the people that live in it, adapt themselves to them, learn from their behavior, and possibly act upon their behalf. This leads to the following list of salient features of Ambient Intelligence into.

- *Integration* through large-scale embedding of electronics into the environment
- *Context-awareness* through user, location, and situation identification
- *Personalization* through interface and service adjustment
- *Adaptation* through learning
- *Anticipation* through reasoning

Evidently, the new paradigm is aimed at improving the quality of peoples' lives by creating the desired atmosphere and functionality via intelligent, personalized, interconnected systems and services. However simple this requirement may seem, its true realization is for the time being not within our reach. To bring this ideology closer to its realization, substantial investigation into integration technology, natural interaction concepts, and human behavior is needed, and this is the aim of Ambient Intelligence.

1.2 Trends and Opportunities

At the occasion of the 50th anniversary of the *Association of Computing Machinery* in 1997, computer scientists from all over the world were asked for their opinion about the next 50 years of computing (Denning and Metcalfe 1997). Their reaction was strikingly consistent in the sense that they all envisioned a world consisting of distributed computing devices that were surrounding people in a nonobtrusive way. *Ubiquitous computing* is one of the early paradigms based on this vision. It was introduced by Weiser (1991) who proposes a computer infrastructure that succeeds the mobile computing infrastructure and situates a world in which it is possible to have access to any source of information at any place at any point in time by any person. Such a world can be conceived by a huge distributed network consisting of thousands of interconnected embedded systems that surround the user and satisfy her needs for information, communication, navigation, and entertainment.

Evidently, the AmI vision closely follows the early developments in ubiquitous computing and it should not be seen as a revolutionary disruption but merely as a natural evolution caused by a number of factors related to worldwide developments which took place at the end of the last century, and that paved the way for a novel concept in the development of electronic systems

and the way people operate them. These factors can be classified into three categories, which relate to developments in technology, global connectivity, and socioeconomic aspects. Below, we briefly elaborate on each of these in more detail.

1.2.1 "More Moore" and "More than Moore"

An interesting frame of reference for our discussion on technology is provided by the developments in semiconductor industry. It is generally known and accepted that developments in this domain follow Moore's law (Noyce 1977), which states that the integration density of systems on silicon doubles every 18 months. This law seems to hold a self-fulfilling prophecy because the computer industry follows this trend for already four decades. Moreover, other characteristic quantities of information processing systems, such as communication bandwidth, storage capacity, and cost per bit of input–output communication, seem to follow similar rules. Advances in Moore's law show the following three lines of development. 1D-Moore is the one-dimensional continuation of the classical Moore's law into the submicron domain of microelectronics, resulting in small and powerful integrated circuits that can be produced at low cost. 2D-Moore is the development of two-dimensional large-area electronic circuitry at extremely low cost, possibly using other technologies than silicon such as polymer-electronics. 3D-Moore refers to the development of ultrahigh functional three-dimensional circuitry consisting of microelectronic mechanical systems (MEMS) that integrate sensor, actuator, computing, and communication functions into a single nanoelectronics system.

Following the lines of thought imposed by the different developments of Moore's law one may conclude that the design and manufacturing of electronic devices has reached a level of miniaturization which allows the integration of electronic systems for processing, communication, storage display, and access into any possible physical object like clothes, furniture, cars, and homes, thus making people's environments smart.

1.2.2 Weaving the Web

What had started in the 1980s as an early attempt to connect the scientific world through a network supporting the exchange of scientific documents and results among researchers had developed by the end of the past century into a truly world-wide network allowing not only researchers but also ordinary people to have access to digital information in the broad sense (Berners-Lee et al. 1999). Access percentages in the western world started to exceed 50% and it soon became obvious that the Internet would grow into a truly ubiquitous access network. Furthermore, the Internet had reached a point in its development were it became evident that the long proclaimed convergence

of mobile computing, personal computing, and consumer electronics would become effective. Nowadays this promise has become reality as many Internet providers offer what they call *triple play*, which is the use of (mobile) telephony, television, and date access over the Internet through a single subscription, and the next step will be the development of the seamless handover between these services among different wirelessly connected devices. In addition to these network developments there were also major developments in the way data were stored in and retrieved from the network. So, people started to develop means not only to store raw data on servers and terminals, but also to generate metadata on the raw data that could provide additional information and support the retrieval process. These developments led to the introduction of the *semantic Web*, which uses all sorts of ontologies among data to enrich the Web leading to the development of high-level applications such as *context aware media browsers* (Berners-Lee et al. 2001).

The developments of the Internet brought a next step within reach, which could lead to a major paradigm shift in the way intelligence was generated among electronic devices. So far the only assumption had been to generate intelligence through complex software programs executed on powerful high-cost terminal devices. Now it would be conceivable to design systems consisting of simple low-cost terminal devices that could fetch intelligence from the network to which they are connected leaving the rendering of the information as the only task to be carried out by the terminal device.

1.2.3 The Experience Economy

By the end of the past century, socioeconomic investigations revealed that a next wave of business development was emerging based on mass customization leading to a new economic order, from which an answer could be obtained on the question whether Ambient Intelligence could contribute to the development of new business and greater wealth to all people in the world. Pine and Gilmore (1999) describe in their compelling bestseller a new economy, which they call the *experience economy*. They position this economy as the fourth major wave following the classical economies known as the commodity, the goods, and the service economy. The general belief of the experience economy is that people are willing to spend money on having experiences, and from certain enterprises such as the holiday economy, one indeed may conclude that this might be very well true. A salient property of an experience is given by the fact that it can feel real, irrespective of whether it has been generated by a real or a virtual cause; what counts is the belly feeling. Personal reminiscences that bring back good old feelings are nice examples of such experiences. Richard Florida (2001) takes the ideas of the experience economy a step further by sketching a world of urban centers in which people create a living by working as artists in the way they create new products and services. These so-called *creative industries* fully exploit the concept of experience design and provide a new economy supplying local-for-local markets.

Prahalad and Ramaswamy (2004) use similar concepts as in the experience economy to propose a new way of value creation for the 21st century based on the co-creation and development of novel goods and services that satisfy the greater needs of customers.

All these novel socioeconomic ideas open up major possibilities for making money in markets that exploit Ambient Intelligent technology, thus providing the necessary economical foundation for the development of Ambient Intelligence.

1.2.4 Advances in Design

In addition to the tree key factors mentioned above, the late 1990s also showed a general development that was following up on the profound desire to have more things that were simply useful, and to move users or people in general into the center of our activities. In other words, the information society had resulted into an overload of products and services for which the user benefits were unclear. There was a call to design things that were easy to understand and simple in their use. Norman (1993); Negroponte (1995) and Winograd (1996) are all examples of designers who were fiercely opposed against the existing means and concepts for user interfaces and man–machine interaction, and who were desperately in search of novel paradigms that would make the interaction with electronic systems more natural. It was generally believed that the social character of the user interface would be determined by the extent to which the system complies with the intuition and habits of its users and this led to a number of groundbreaking insights. One of these developments is that of a novel research area which is called *affective computing*, and which is characterized by a multidisciplinary approach to man–machine interaction that combines different methods from psychology and computer science (Picard 1997). Another angle is provided by the approach followed by Reeves and Nass (1996) who state in their *Media Equation* that the interaction between man and machine should be based on the very same concepts as the interaction between humans is based, i.e., it should be intuitive, multimodal, and based on emotion. Clearly, this conjecture is simple in nature but it has proved to provide many designers with some foothold in the development of their products. Loosely related to this is the concept of *user-centered design* (Norman 1993; Beyer and Holtzblatt 2002), which is applied by many interaction designers. It states that the user is to be placed in the center of the design activity, which follows a number of consecutive design cycles in each of which the designer reevaluates her concept and its realization through specific user evaluations and tests.

The development of the AmI vision has been largely influenced by these design developments because they clearly articulated the need for a user-centric approach to the design of novel electronic environments. They also

contributed to the understanding that the use of Ambient Intelligent environments can only be measured by the user benefits that are ultimately achieved by them, irrespective of their intricacy and sophistication.

1.3 A Brief History of Ambient Intelligence

In this section, we briefly review some of the AmI developments. Although Ambient Intelligence is still young, its development over the past years shows a number of interesting landmarks. Obviously, the origin of Ambient Intelligence is tightly coupled to the groundbreaking developments in computing science imposed by the developments in ubiquitous computing. Its unique identity, however, is imposed by the fact that the AmI vision is to a large extent a user-centric industrial vision with a major impact on scientific research.

1.3.1 Early Developments at Philips

The notion of Ambient Intelligence was developed in 1998 in a series of internal workshops that were commissioned by the board of management of the Philips company. The workshops were aimed at investigating a number of different scenarios that would lead a high-volume consumer electronic industry from the current world which was called *fragmented with features* into a world near 2020 with fully integrated user-friendly devices supporting ubiquitous information, communication, and entertainment. Palo Alto Ventures, a US management consultancy company, acted as the facilitator (Zelka 1998). The first public presentation on Ambient Intelligence was given at the Digital Living Room Conference 1999 by Roel Pieper who at that time was a member of the board of management of Philips Electronics responsible for consumer electronics equipment (AmI Keynote 1999).

The first official publication that mentions the notion "Ambient Intelligence" appeared in a Dutch IT journal (Aarts and Appelo 1999) and emphasized the importance of the early work of the late Mark Weiser who already for more than ten years was working on a new concept for mobile computing which he called ubiquitous computing (Weiser 1991).

The AmI vision has also been used by Philips Research to establish new and promising collaborations with other strong players in the field. In 1999, Philips Research joined the Oxygen alliance; an international consortium of industrial partners that collaborated within the context of the MIT Oxygen project (Dertouzos 1999, 2001). The Oxygen project is a joint effort of the MIT Computer Science Laboratory and the Artificial Intelligence Laboratory, and it aimed at developing the technology for the computer of the 21st century. It allows multimodal controlled handheld communication units to connect through environmental units to a broadband communication network, thus supporting ubiquitous information access and communication.

In the mean time the vision grew mature. In 2000, first serious plans were launched to build an advanced laboratory that could be used to conduct feasibility and usability studies in Ambient Intelligence. After two years of designing and building, HomeLab was eventually opened on 24 April 2002 (Aarts and Eggen, 2002), and the opening event officially marked the start of a new research program on Ambient Intelligence at Philips Research (de Ruyter 2003). In 2003, Philips published *The New Everyday* (Aarts and Marzano 2003). The book contained over 100 contributions on Ambient Intelligence on a broad range of topics ranging from materials science up to marketing and business models. Most of the contributions are from Philips authors, but about ten of them are from renowned specialists emphasizing various aspects related to Ambient Intelligence ranging from promising new applications to critical remarks that warn for the possible societal disorientation that might result from Ambient Intelligence. *The New Everyday* can be seen as the first in a series of activities undertaken by Philips to open the vision by sharing the ideas Philips had developed so far with a broader audience.

1.3.2 Opening up the Vision

Along with the build up of the vision for Philips, a parallel track was developed which was aimed at positioning the vision as an open initiative for the advancement of the innovation in information and communication technology in Europe. Following the advice of the Information Society and Technology Advisory Group (ISTAG) (ISTAG 2001) issued in 2001, the European Commission used the vision for the launch of their sixth framework (FP6) in IST, Information, Society, and Technology, with a subsidiary budget of 3.7 billion euros. The influence of the European Commission has been crucial for the development of the vision and it is hardly conceivable that the paradigm could have grown in the strong way it did without the Commission's support. The reason for this is obvious. It soon had become evident that a single company, however big, could not turn a vision as broad as Ambient Intelligence into reality. A neutral and influential party was needed to bring the different stakeholders together and facilitate and manage the development processes. As a result of the many initiatives undertaken by the European Commission the development of the AmI vision really began to gain traction. These initiatives resulted in the start of numerous research projects that were aimed at the development and realization of the vision. Last year's IST Conference in Den Hague featured results of more than 30 major projects on a large diversity of applications including personal health care, consumer electronics, logistics and transportation, and e-mobility (IST 2004).

At the same time, the vision was recognized as one of the leading themes in computing science by the Association for Computing Machinery (ACM), and as a result thereof a book chapter on Ambient Intelligence was invited to the book *The Invisible Future* (Aarts et al. 2002). The book was published at the occasion of the ACM1 conference, which was aimed at providing the

electrical engineering and computer science community of the world with new insights into the future of computing at large. In addition to the chapter on Ambient Intelligence, the book contains a wealth of contributions from various renowned scientists in the world expressing their vision on a variety of subjects ranging from computer hardware and programming up to health, education, and societal issues.

During the past years several major international initiatives were started. Fraunhofer Gesellschaft originated several activities in a variety of domains including multimedia, microsystems design and augmented spaces. Their *In-Haus* project (inHaus, online), which is similar to Philips' *HomeLab* a research facility that supports investigation into feasibility and usability aspects of Ambient Intelligence, can be seen as a first approach to user-centric design and engineering. MIT started an AmI research group at their Media Lab with a special emphasis on research in personal health care. More than ten 5 million euros or more research programs on Ambient Intelligence were started at national levels in a large variety of countries including Canada, Spain, France, and The Netherlands. A novel European subsidiary instrument has been announced under the name Experience and Application Research Centers, which is aimed at the financial support of research facilities that conduct research into user behavior for the purpose of user-centric design and co-creation of novel products and services inspired by the vision of Ambient Intelligence.

Over the years, the European Symposium on Ambient Intelligence (EU-SAI) has grown into the most interesting event for the exchange of novel ideas in Ambient Intelligence (Aarts et al. 2003; Markopoulos et al. 2004). In addition to EUSAI, which is devoted to Ambient Intelligence only, many large key conferences have started to set up special events highlighting developments in Ambient Intelligence that are of interest to their audience. Examples are DATE03, CHI2004, INTERACT2004, CIRA2005, and INDIN2005.

In the mean time, several books have been published which deal with different aspects of Ambient Intelligence. (Mukherjee et al. 2005) discuss physics and hardware related aspects including microelectronic systems, large-area electronics, and MEMS design. Weber, et al. (2005) present a collection of edited chapters on a variety of technological aspects including connectivity and low-power design. Basten, et al. (2003) discuss challenges in embedded systems design related to Ambient Intelligence. Verhaegh, et al. (2003) present a collection of edited chapters on the design and analysis of Ambient Intelligent algorithms. Riva et al. (2005) present a collection of edited book chapters on sociocultural aspects of Ambient Intelligence.

1.3.3 Where Are We Headed?

Over the past years, the awareness has grown that the classical type of industrial research facility can no longer provide the technological innovation required to drive the world's economical development. For more than half a

century industrial research laboratories applied the policy that hiring the best possible people and stimulating them to generate as much as possible intellectual property rights would provide the most effective way to technological innovation. Many of the existing industrial research laboratories consider the protection of their knowledge as quite important and consequently the nature of these laboratories reflects that of a closed facility. More recently, new models for industrial research were proposed that followed the developments of the networked knowledge economy. Based on the belief that tapping into as many as possible bright people can develop more innovative ideas, industrial research has widened its scope to become more collaborative and open-minded.

Ambient Intelligence has proved to be quite instrumental in the realization of open innovation. The broadness of the vision allows many different parties to contribute from within their own specific angles. Looking at Europe we see again a number of interesting initiatives that are aimed at international collaboration. The *AmI@Work* (online) group combines parties from both the public and the private domains to provide a forum for the discussion of the use of Ambient Intelligence to improve productivity and support health care and well-being. The European Technology Platform for the development of embedded systems called *Artemis* uses the AmI vision to define their strategic research agenda. In addition to the many activities by the European Commission, there are also private initiatives that are aimed at international collaboration. As an example we mention AIR&D, the Ambient Intelligence Research and Development consortium in which INRIA, Fraunhofer Gesellschaft, Philips, and Thompson jointly conduct precompetitive research in Ambient Intelligence. These are just a few examples of a large variety of novel and promising initiatives that use the AmI vision to support open innovation.

So after five years of successful developments, one may wonder which direction Ambient Intelligence will take from here. For the longer term this question is hard to answer because its answer will be strongly influenced by the many external factors that determine the success, and hence the lifetime of a vision such as Ambient Intelligence. There are two key factors for success that can be mentioned. The first one is given by the extent to which Ambient Intelligence can drive innovation processes that turn into business successes, and the second one is determined by the length of time over which researchers will stay inspired by the vision and are willing to contribute to its realization. For the shorter term, i.e., the next one or two years, however, the answer is obvious and determined by output that will become available from the many initiatives that have been defined for this period of time. All in all the forthcoming years promise to become very inspiring for the development of Ambient Intelligence with many new challenging initiatives that carry the promise to contribute substantially to the fruitful realization of the AmI vision.

1.4 Realizing Ambient Intelligence

Ambient Intelligence will make a substantial contribution to science, as well as to the economy, if its realization contributes noticeably to human well-being. The cycle of technology becoming increasingly difficult and inscrutable in its usage must be broken. Up to now, it has been the user's responsibility to manage her personal environment, to operate and control the various appliances and devices that are available for her support. It is obvious that the more the technology is available and the more options there are, the greater the challenge of mastering your everyday environment of not getting lost in an abundance of possibilities. Failing to address this challenge adequately simply results in technology that becomes inoperable and thus effectively useless.

1.4.1 For the Well-Being

It seems to be contradictory, but the more options and functionalities a bundle of devices offer to their users, the more functions remained unused. But the reason is simple: Technology as it exists today forces its metaphors upon the user. The responsibility of finding a strategy that combines all the functions that are offered by the environment equipped with smart devices and functionalities is shifted to the user. Consequently, it is possible for the user to be more occupied with finding strategies and functions than she is with her actual goals.

Stated more emphatically: with increasing technology, the user is in danger of losing sight of her goals or of changing her goals, because she is not able to find the appropriate combination of strategies for device functions. The user is forced to pay more attention to complete lists of functions than to her actual goal. Instruction manuals for today's devices are a good example of the metaphor change that took place. These manuals explain menu-based selection lists or parameter adjustments. But the instructions do not explain the possible user goals, which can be achieved by using the corresponding device. Furthermore, which goals could be achieved, if devices were interconnected, is generally not mentioned at all.

In summary, technological development has shifted in the last few years from goal orientation to function orientation. The development effort concentrated more on the extension of the pool of functions than on the user and her goals and her well-being. The most important task of Ambient Intelligence is to reverse this metaphor change back to the user's goal orientation (see Fig. 1.1). Technology has to meet the wants of the user and not vice versa.

Through Ambient Intelligence, the environment gains the capability to take over mechanical and monotonous control tasks – as well as stressful feature selections and combinations – from the user and manage appliance activities on her behalf. To do this, the environment's full assistive potential must be mobilized for the user, tailored to her individual goals and needs. Realizing this, the user becomes an active part of her environment; she will be
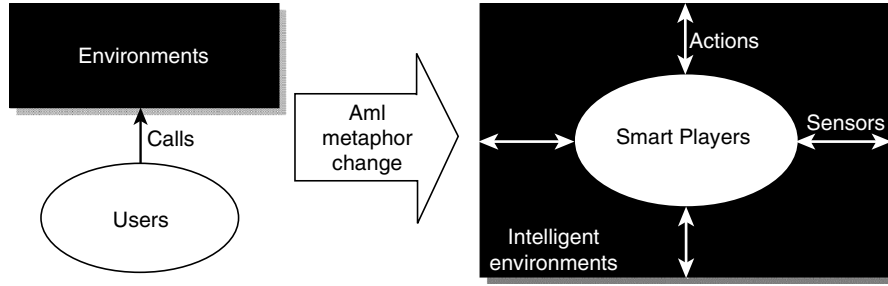
Fig. 1.1. The metaphor change of Ambient Intelligence from function orientation to goal orientation effects that a user becomes a smart player within a proactive intelligent environment

more than only a user who is trying to reach her goals by using the available environment technologies. The user becomes a *smart player*, who is proactive assisted by her environment. The term smart player indicates that the interaction of the user and the environment changes from unidirectional to bidirectional. Thus, it expresses the awareness of the environment in respect of the smart player's needs and goals (in the following the terms *user* and *smart player* are used as synonyms).

Consequently, Ambient Intelligence extends the technical foundation that was laid by former initiatives like *ubiquitous computing* and *pervasive computing* respectively. These technologies triggered the diffusion of information technology into various appliances and objects of the everyday life. But now, Ambient Intelligence has to guarantee that those smart devices behave reasonably and that they unburden – instead of burden – the user. This means, the approach of the former initiatives, which is more technology-oriented (innovations by *technology-push*), must be replaced by a more user- and scenario-oriented approach, respectively (innovations by *user-pull*). Consequently, Ambient Intelligence enables the smart player to concentrate on what she ultimately wants to achieve: her actual goals.

1.4.2 Reorientation

The AmI vision is aimed at creating a reactive and sensible (one can also say "intelligent") environment for the smart player's needs and well-being, the basic requirements are the following:

– The environment (and its devices) must be aware of the smart player's current situation, her interaction within her environment and its own current state (and possible changes in this state).
– In addition, the environment must be able to interpret those occurrences into user goals and, accordingly, into possible reactions that enable a cooperative, proactive support for the user.

– In a final step, the environment must be able to translate the interpreted goals into strategies that can be fulfilled by the environment's devices and functionalities in order to adapt itself to the smart player's needs.

This cycle can be called the *Principle Workflow Cycle* of Ambient Intelligence. Regarding each step of the workflow cycle, Ambient Intelligence forces the scientific – and also the industrial – community to think about different challenges and to find appropriate solutions for them. Some of the arising questions should be mentioned at this point:

– *"How does the user interact with her environment and what does she wish to express?"*
  Of course, if input from the user is necessary, the environment should speak the language of the user. The user must be allowed to interact in a natural way, by means of voice or gestures. But there is more to it than that. To assist the user in an effective way, Ambient Intelligence affects a transition from a function-oriented interaction with devices to a goal-oriented interaction with device systems. The user should be able to express goal states rather than select functions of devices. It means that the interaction metaphor has to change from the device-oriented vocabulary to a more user-oriented vocabulary. The environment must speak the language of the user and not vice versa. Consequently, Ambient Intelligence demands a transition from conventional unimodal, menu-based dialog structures to polymodal, conversational dialog structures that assist the user in defining her goals rather than selecting function calls.
– *"How should an ensemble of devices interoperate?"*
  It cannot be expected that the user is able or even willing to orchestrate multiple – invisible!? – devices in order to fulfill her needs. Particularly, if the user is not aware of each individual device and its functionalities. Consequently, device ensembles that define the environment have to provide methods of self-organization. That means the interoperability of devices must be guaranteed, but also their extensibility and reliability. Ambient Intelligence must dismantle the handcrafted design and implementation of component and device ensembles as it is done today and must replace them with new methods of self-organized ad hoc device cooperation. That means the technology must move from an accidental collection of independent devices to a system that acts as a coherent ensemble.
– *"How should an ensemble react to environmental changes and user interactions?"*

The environment, in which the user is located, should do the obvious. That means in technical terms that the environment variables that determine the actual state of the environment should change reasonably in order to fulfill the user's goals. Obviously, the environment – that is defined by its devices – should not demand any input from the user if her intentions can be inferred from the given context. Consequently, to realize the vision of Ambient Intelligence, devices and components are needed that behave context aware and,

above all, reasonably. Device ensembles should do what is obvious for the user and what corresponds to the personal preferences of the user and the current state of the environment.

In summary, the AmI vision – to create reactive environments to reasonably assist the smart player according to the given context and her preferences – will cause some technological reorientations. That will involve, for example, self-organizing component and device ensembles (Encarnação and Kirste 2005), but also innovative multimodal interaction technologies, machine readable and understandable ontologies, visualization technologies, and also the integration of Artificial Intelligence into context-aware solutions. The usage of technology will realign from pure function orientation to being smarter player- and goal oriented.

1.4.3 Impact Through Integration

The paradigm shift from function to goal orientation that is affected by the vision of Ambient Intelligence will create a stronger link and cooperation between different technologies and also activate new interdisciplinary research activities for many different branches of research. Science and industry will also be motivated to purposefully work for the well-being and the needs of humans.

Therefore, Ambient Intelligence must integrate scientific subjects like human–computer interaction, middleware and agent technologies, or virtual reality and different disciplines of computer science, such as context management or Artificial Intelligence, into one cooperative vision. Furthermore, more hardware-oriented branches of research, such as nanotechnologies or embedded systems, mobile technologies or sensor technologies, awareness and presence technologies, must be homogenously integrated to create new devices, products, and systems, but also new kinds of content, integrated and personalized services and applications, in order to pursue the goal of realizing the AmI ideas (see Fig. 1.2).

In addition, Ambient Intelligence will make it necessary for different research fields to cooperate. This means new kinds of multidisciplinarity have to be established in order to make the integration of different technologies possible, as well as to integrate nontechnological disciplines like psychology, social science, or medical science. Because the concepts of Ambient Intelligence may not be limited to a certain culture domain the applicability of AmI solutions and implementations across different cultures has to be verified and specialization toward the specific features unique to individual cultures has to be provided. Consequently, multiculturality will have a strong impact on the realization of AmI scenarios.

Besides multidisciplinarity and multiculturality, interoperability must not be forgotten. If the interoperation and the cooperation of devices and components that are developed by different companies or vendors in different nations
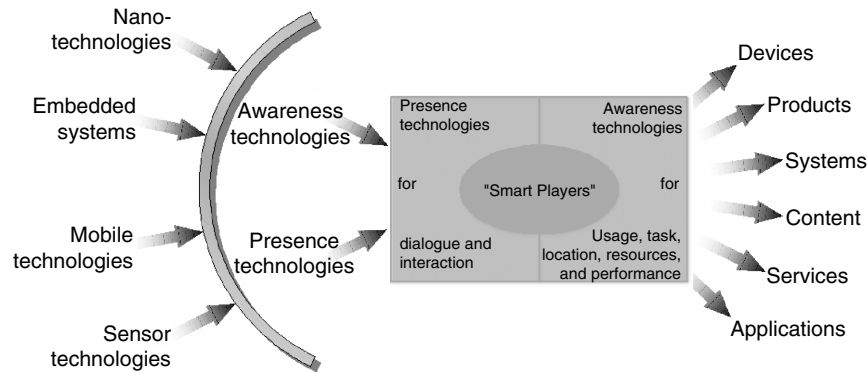
Fig. 1.2. The enhancement of different technologies and their application in AmI scenarios in an integrated fashion will lead to new products and systems

were to be guaranteed, AmI scenarios could be assembled ad hoc from different stand-alone devices that autonomously configure themselves into a system that acts as a coherent ensemble.

Thus, Ambient Intelligence burdens those who want to make all of this happen with strong requirements, because it demands the cooperation of multiple research branches and the consideration of the needs and characteristics of different cultures, as well as (technical) interoperability. Only if all requirements are accomplished AmI technologies will be eventually accepted by the majority of the users and result in both scientific and economic success.

1.4.4 Turning Vision into Reality

Obviously, in order to realize Ambient Intelligence, sizable advances in a multitude of research fields are necessary, not only in the field of software engineering but also in interdisciplinary fields like human–computer interaction. For the implementation of Ambient Intelligence, the following two research tracks must be taken in parallel and in close cooperation.

– The further development of certain technologies (e.g., the enhancement of centralized agent platforms to self-organizing decentralized component ensembles, the construction of intelligent scenarios and rooms – not in a hand-crafted way, but in such a way that devices configure themselves autonomously according to the given smart player goals, or the enhancement of poly-modal dialog technologies).
– The development and implementation of AmI scenarios under strict consideration of the smart player's needs her preferences and her cultural demands.

The requirements of the smart players must directly affect the development the adjustment of AmI technology and vice versa the enhancement of technology may only happen under consideration of the smart player's needs.

The Fraunhofer Gesellschaft, the largest organization for applied research in Europe, bundles its efforts towards the realization of Ambient Intelligence in an appropriate initiative under the leadership of the Institute for Computer Graphics in Darmstadt (Fh-IGD) and the Institute for Open Communication Systems in Berlin (Fh-FOKUS). First, some scenarios are analyzed to examine the requirements and the needs of users while interacting in their home, in their car, or in their office. Cars could recommend points of interest in the nearby surroundings or could provide the user with her favorite music. The car could also manage incoming telephone calls in accordance with the current driving situation, thus preventing the driver from engaging in dangerous driving behavior.

The intelligent house organizes the shopping according to the preferences of the residents, but also under consideration of their personal date planner (in case there are guests to be entertained). Particularly the needs of the elderly receive special consideration. Loudspeakers and microphones in the room where the resident stays manage telephone calls. The house contacts the relatives or the physician in case the person's vital functions experience a change for the worse. However, not only humans, but also animals or even work pieces in production can profit from the developments in Ambient Intelligence. Animals and work pieces can also be the smart player in AmI scenarios. By means of self-organization, work pieces will find the most appropriate machine that corresponds best to its task schedule for instance. Thus, Ambient Intelligence will open up the way for the self-organizing factory and new kinds of logistics.

The result of the detailed specification of possible AmI scenarios is a complete definition of the affected environment variables and their values, a complete pool of possible user and environmental goals, as well as their implication on environmental changes. Finally, possible conflicts (between devices and/or components) are identified and appropriate conflict resolution mechanisms are found.

Those results form the basis of the definition of the AmI workflow, which defines a reasonable workflow cycle from (user) interaction via goal detection to environmental changes. The results also form the basis for the definition of the AmI application space, which defines the basic functionalities that have to be provided to realize AmI scenarios.

Afterwards, detailed requirements concerning the AmI technologies could be specified. Certainly sensor and monitoring technologies, self-organizing middleware technologies, and multimodal interaction technologies will have to be developed or adjusted. Some requirements concerning machine-readable ontologies or inference and strategy engines will also emerge.

The last step in making a huge step towards Ambient Intelligence is to implement the proposed scenarios by assembling the developed technologies. The AmI initiative of the *INI-GraphicsNet* (AmI@INI, online) that was established in 2004 forms the basis of the described research approach. In addition the Fraunhofer Institute for Computer Graphics is involved in several

projects that are researching certain AmI issues. The project DynAMITE, (online) for example (an abbreviation of DYNAmic Adaptive Multimodal IT Ensembles) researches the topology of AmI component ensembles as well as implements a self-organizing middleware for the composition of device ensembles (Hellenschmidt and Kirste 2004a,b). In order to manipulate devices – also in foreign environments – the *Personal Environment Controller* (PECo, online) provides a three-dimensional visualization of the room to allow the user to interact directly with her environment. Thus new kinds of interaction for direct manipulation instead are investigated.

In a nutshell: Ambient Intelligence could become reality, if researchers from different research fields share the same vision of a future where all of us are surrounded by intelligent electronic environments that are sensitive and responsive to our needs and if those researchers cooperate to define a common reference model that builds the basis for the development of new technologies and new assistive proactive scenarios.

1.5 Ambient Intelligence Becomes a Success

Ambient Intelligence implies a seamless environment of computing, advanced networking technology and specific interfaces where the smart player is assisted by reactive environments according to the given context, and her personal needs and preferences. Because Ambient Intelligence will have a strong impact on science as well as on economy, it represents a long-term vision for the EU Information Society Technologies Research program. To be successful, researchers across multiple disciplines like computer science, engineering but also social science and psychology will have to cooperate. This cooperation will be the key for future technical innovations and for the development of effective applications. But Ambient Intelligence becomes a success only if the needs of the smart players are in the focus of the cooperative research activities. Consequently, the vision of Ambient Intelligence creates a strong link between interdisciplinary research fields, leading to new innovative technologies and applications, and finally strengthening science and economy.

One of the major new things in Ambient Intelligence is given by the development to involve humans in the design and creation of novel concepts and products. This call for application and experience research extends far beyond the classical approaches to user-centered design in terms of manner and the extent in which the end-users are involved. Most classical design methods adopt a more-or-less static approach in which functional user requirements are first elucidated through use-cases or target-group studies and subsequently transformed into design requirements. Ambient Intelligence calls for an approach in which users are an integral part of the design and operation of their environment, thus enabling them to live and work in a surrounding that stimulates their productivity, creativity, and well-being in an active way.