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Perspectives of ambient intelligence in the home environment☆

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Abstract

Ambient Intelligence is a vision of the future information society stemming from the convergence of ubiquitous computing, ubiquitous communication and intelligent user-friendly interfaces. It offers an opportunity to realise an old dream, i.e. the smart or intelligent home. Will it fulfil the promises or is it just an illusion—offering apparently easy living while actually increasing the complexity of life? This article touches upon this question by discussing the technologies, applications and social implications of ambient intelligence in the home environment. It explores how Ambient Intelligence may change our way of life. It concludes that there are great opportunities for Ambient Intelligence to support social developments and modern lifestyles. However, in order to gain wide acceptance a delicate balance is needed: the technology should enhance the quality of life but not be seeking domination. It should be reliable and controllable but nevertheless adaptive to human habits and changing contexts.
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1. Introduction

1.1. Ambient intelligence

"Ambient Intelligence" (AmI) is not a prediction of the future but a vision. It refers to the future of the information society stemming from the convergence of ubiquitous computing, ubiquitous communication and intelligent user-friendly interfaces as envisaged by the European Information Society Technology Advisory Group (ISTAG, 2001, 2003). It puts the emphasis on user-friendliness, user-empowerment and support for human interactions.

Ambient intelligent environments will be characterized by their ubiquity, transparency and intelligence (Aarts and Marzano, 2003). ICT-based artefacts and computers would fade into the background while people would be surrounded by intelligent and intuitive interfaces embedded in all kinds of objects. The environment would recognize individuals and some of their needs and wants, as well as changes in individuals, changes in needs and wants, and changes in the environment. It would respond in a seamless, unobtrusive and often invisible way, nevertheless remaining under the control of humans. Intelligent agents would eventually make decisions that automatically serve a person or notify a person of a need to make a decision or to carry out an action (adapted from Ferguson, 2001).

The AmI vision is by definition normative and aims more at contributing to shaping a desirable future than describing it realistically. However, as AmI puts a major claim on being people-oriented, user-friendly, unobtrusive and controllable, it thereby also assumed it AmI will be inclusive for a large share of the society (Punie, 2003, 2005). The key question is therefore whether AmI will fulfil some or most of the promises researchers are making or whether it is just an illusion—offering apparently easy living while actually increasing the complexity of life.

1.2. The IPTS/ESTO roadmapping project

In August 2002, the Institute for Prospective and Technological Studies (IPTS) of the European Commission's Joint Research Centre, and the European Science and Technology Observatory (ESTO) launched a project aimed at developing science and technology roadmapping (S&TRM) as an input into policy making at European level (Friedewald and Da Costa, 2003; Alahuhta and Heinonen, 2003). Three main issues underpinned the project:

- What are the major societal challenges facing Europe?
- What are the emerging technological responses to these challenges?
- What are the pathways between these challenges and responses?

Technology roadmapping is a widely used methodology, employed by individual companies, entire industries and public research institutes (Da Costa et al., 2003) as a way of bringing together various stakeholder perspectives so as to develop an overview of how a technological field, or an industry is likely to develop over a set future period. It is used for displaying and synthesizing networks of past, present and future stages of S&T developments, components of strategies, causes or solutions to a problem, potential disruptions, and for highlighting the necessary steps to reach the market with the right products at the right time. It traditionally endorses a technology-push approach but it is getting increasingly applied to analyzing the scientific and technological, economic, political and social dimensions of a wide range of fields, and the interactions between them.

In this context, the applications of Ambient Intelligence in the Home Environment were explored. Functions were identified where AmI is expected to "make a difference". Focusing on functions enables to take into account both foreseeable AmI applications and everyday behaviour (social trends) (Da Costa and Punie, 2003).

In the following sections, technologies, applications and social implications of ambient intelligence in the application field of Housing will be discussed.

1.3. Intelligent homes: history, trends and gaps in R&D

Visions of highly automatised Homes with futuristic technologies have been developed for decades already under various buzzwords such as Intelligent Home, Smart Home, Interactive Home and Home of the Future. The tasks charged on the Smart House (Scott, 1998) are by no means negligible:

- It helps its inhabitants live a healthy, happy and safe life;
- It performs many tasks automatically to relieve the stress of managing the house;
- It integrates home, work, learning and leisure activities;
- It does not annoy people with the technological details of how it actually works.

During the last few years the scientific literature concerning the topic of intelligent houses/buildings has diversified. The term "intelligent" has become somewhat outmoded or obsolete, being replaced by new approaches such as "aware house", "integrated environments" or "alive and interactive environments". Authors have diverted their interest in studying more the interaction between home and residents and related interfaces than technologies as "intelligent" in their own right. This change appears analogous to the shift of emphasis from techno-centred artificial intelligence towards human-centred ambient intelligence, ubiquitous intelligence/computing or versatile intelligence/computing.

The main trends driving the application of ambient intelligence technologies in the application field of housing have been found to be:

- The acceleration of rhythm of everyday life, hectic and busy lifestyles, growing demands of efficiency and flexibility in daily routines;

- The breaking up of the boundaries of time and space (increasing telepresence);
- The ageing of population, leading to a demand of elderly living longer in their homes;
- The increasing demand of security and safety (e.g. due to rising crime rates and/or sense of insecurity);
- The growing pressures to curb environmental problems and to save energy (to promote sustainable development and to compensate high prices of energy);
- The increasing search for experiences and meanings (e.g. Jensen, 1999, 2000) (leading to building homes as media/entertainment centers);
- The increasing need for home as a sanctuary (home as dedicated to privacy, rest and relaxation);
- The technological way of life per se of many young urban people.

Undoubtedly, new technologies have changed our life in the last decades. They can make three types of contributions to improve our everyday life:

- They can have practical use by making many everyday tasks easier and faster;
- They can provide enjoyment, playfulness, fun and aesthetics;
- They can increase the status or prestige: the early refrigerator advertisements in the late 1920s put emphasis mostly on prestige and novelty and refrigerators were designed to appeal to an average homemaker as much aesthetically as practically. (Nickles, 2002, p. 697).

Practical use or improved productivity have been (and are) most of the times the main selling argument concerning new innovative domestic technology. As Castells (1996, 397f.) points out "home centeredness" is an important trend of personal and professional life. People do increasingly work and manage services from their home. However, the real expectations, needs and desires of people concerning intelligent home are more complex and are being intensively researched and analyzed.

In the physical world, home, domicile and residence are well-understood concepts. Sceptics on the role of technology quite rightly emphasize that Home is neither a Machine, nor an array of technological tools that only help the residents lead and survive everyday life. Home is for Humans, whose quality of life, and the perception of it, is expected to improve via technology and ambient intelligence. It is an emotionally charged and personally furnished cradle of living, physical space as much as a socio-cultural context and a state of mind. It is more than always expected to provide a safe haven of communication and caring, rest, relaxation and entertainment. Paradoxically, home can be characterized as being "wired" in order to "unwire" (relax) its occupants.

Home is not just for a juxtaposition of individuals but also for a family, a community. Intelligent Home should be analyzed from the perspective of supporting families and friends being together and interacting between each other. There is a case to be made for developing and establishing the notion of 'virtual residence' as an extension of the physical residence. It should contribute to a better perception

and consideration of ones' personal digital territory and could help to tackle the blurring boundaries of what is public and private in the online world.

2. AmI functions and solutions in the home environment

The application field of Housing is wide, since people spend more time in their homes than in any other space (Intille, 2002, p. 76). Home is concerned with people, spaces, rooms, environments, furniture, equipments, artefacts, ornaments and their various combinations in terms of time and space. There are four basic functions the housing application field will cover:

- Home Automation (Basic Housing Supporting Functions),
- Communication and Socialisation,
- Rest, Refreshing, Entertainment and Sport,
- Working and Learning.

All these functions share as a common feature the purpose of responding to the users' needs and preferences in housing. However, the functions regulated and controlled by home automation are elements and functions of the house itself and its critical "living conditions" as a prerequisite for Humans living in the house. The house itself is the major agent while people moderate and control these functions.

The rest of the functions here dwelled upon are more centred on the residents themselves. They represent the functions people do more directly for themselves. People are major agents, while the house with its ambient intelligence provides optimal context for such activities.

2.1. Home automation

The home automation function covers basic housing supporting functions, the Security functions and the functions to increase the autonomy and support the independent living.

2.1.1. Basic housing supportive functions

In home automation the main idea is to make the control of existing functions (e.g. heating, plumbing, ventilation, air-conditioning or HPAC, lighting, as well as electrical and other installations: fire and burglary alarms, control of electronic appliances) easier, integrated and/or even automated.

Most of the functions of home automation system exist currently without any intelligence. People can control lights or heating using existing switches and controls. The user needs have been analyzed in depth and proprietary solutions providing these applications have already found their market (Rentto et al., 2002). For instance, at Dallas/Fort Worth Airport, the lights are controlled by sensors that measure sunlight. They dim immediately when it is sunny and brighten when a passing cloud blocks the sun. At a new middle school in Washington, DC, the air conditioner

shuts off when a window is open. A wall of windows at a University of Pennsylvania engineering building has built-in blinds adjusted by a computer program that tracks the sun's path (Simon, 2004).

In the intelligent home these functions will be controlled through touch panels and eventually by voice, hand gestures, face expressions, etc. Ambient intelligence here means that the home automation system identifies the resident and adjusts these functions according to the known preferences taking into his/her moods and some external parameters. The favourite kind of music or TV channel is automatically turned on, certain degree of lighting and heating is put on, window shades adjusted, etc.

The functions controlling physical environment, e.g. functions related to HPAC and security, have high requirements for reliability and fault tolerance. The comfort of use is important but only secondary to these. Hence, the system must be designed so that, e.g. home server failure does not cause uncontrolled behaviours of these systems (Cluitmans et al., 2002). For instance, sudden turning off the lights in a cramped room may result in accidents.

A major challenge for ambient intelligence applications is to decide on whose preferences the functions are chosen in a shared space when more than one person is present. Even when only one person is present, there should be enough intelligence to guess, e.g. from the facial expressions which kind of mood the resident is in at the moment.

2.1.2. Security

Within Maslow's theory of human motivation (Maslow, 1943), safety (security, protection) is the second need to be satisfied, just after the basic physiological needs (food, water, shelter). Security of the persons and goods is becoming in all the developed countries one of the major concerns and one of major divers of ICT products and technologies.

Security can be divided into functions controlled through home automation:

- Security in terms of Physical Access Control and Burglary Alarm systems,
- Security in terms of health and wellbeing of the residents (prevention, monitoring),
- Security in terms of safe construction (and materials), the monitoring and control of the "health" of the building itself (Snoonian, 2003). This can also be seen as part of the basic functions supportive functions as depicted in the previous section.

These functions are mostly based on using ICTs for maintaining various alarming systems (both for theft prevention and accidental events caused by the elderly, disabled, children, pets, wild animals, etc.).

Physical access in houses today is controlled mostly with mechanical locks. The demand for more advanced locking and identification systems is growing in parallel with the rate of burgling in most, if not all, developed countries. Locks capable of identifying persons and permitting hands-free opening would be useful for several

population groups: elderly, children and disabled, as well as parents entering home with both hands carrying shopping bags and guiding several children along. More widespread use of electro-mechanical locks and doors makes digital access control viable. The access control can be then handled with electronic keys such as magnetic cards, RFID tokens or biometrics or the combination of both. Biometric access control solutions should become affordable for private homes within the next five years. Leading biometric methods are fingerprint and iris, while face recognition still needs maturing. Voice recognition offers natural interaction at the cost of lower security. The main challenges for biometric methods today are their insufficient usability and public acceptance.

Two other features may be linked to physical access and biometrics:

- the surveillance with cameras and other sensors and
- the use of biometric recognition in personalization of the home services, e.g. choosing the right TV-channel and volume based on user's identity.

2.1.3. Support of the independent living

In a context of ageing population, social security deficits and labour-scarcity, the aim is to develop tools increasing the autonomy and supporting the independent living of disabled and elderly people, so as to enable them to play a more important role in society. Due to the high costs of the institutional living, there is an important incentive for the social security and pension systems to encourage such tools if the evidence of prolonged independent living is provided. A low user cost is a key factor of success. These tools could be adapted to the need of people in charge of young children or even pets.

These tools should include not only means to monitor safety, health status, location and needs of people, but also to compensate possible functional impairments (e.g. remote control of different electronics appliances and doors), add security (fire and burglary alarms forwarded to caregiver, automatic protection mechanisms for electronic appliances such as iron and oven), and provide improved communication means.

Hence, there is a need for several technical aids simultaneously, giving potential advantages for their integration into the same platform. The expected operation should be mainly invisible to the user especially as far as wellness monitoring is concerned (e.g. logging health data to the database). Single data items do not bear a great value (i.e. missing single measurement results is not a catastrophe, while missing a single fire alarm would be), and the long-term follow up brings real added value to the user (Cluitmans et al., 2002). The fears for technology substituting human touch are eminent.

2.2. Communication and socialisation

Home is the place for various types of communication and socialisation, and these functions are central into the visions of the future home. ICTs are already

supporting, facilitating and speeding up communication, and thereby socialisation, inside the home as well as to and from home, access to outside world through Internet and to other information systems. The development of devices (especially in computing) has moved from non-intelligent terminals to hand-held and hands-free devices. On the one hand, sensing and interactive interfaces and on the other hand, user-friendly and compatible devices are needed. The developments will largely be driven by "what consumers will pay for" (Stock, 2002). However, it must be born in mind that the most important communication and socialisation, such as the tenderness of parents towards children, do occur without and do not need any technological support.

2.2.1. Person to person

Fixed-line telephones have been already for decades the most widespread communication artefacts. In developed countries practically all apartments and houses have a fixed-line telephone access point. Cordless phones attached to a fixed-line network have been an improvement in increasing the mobility, but have not changed the paradigm: "One phone for one house".

Mobile phones have been a success story in communication technology. With the increased penetration of mobile phones, communication between people has turned increasingly personal "One-phone for one person", also adding the "always connected paradigm". The capacity to remain always in touch with loved ones or working environment has the senses of belongings and security and the efficiency in personal and professional life. However, as work has increasingly intruded to the home, the 24-h-availability also means great danger of stress and threats to the quality of personal and family life.

More recently, the modalities of person-to-person communication are being diversified by the development of mobile photo and mobile video techniques.

2.2.2. Person to community

A heavy trend of modern life is that people are becoming more nomads, moving and travelling, changing jobs, etc. More and more family are leaving in different countries or even continents. Separations for professional reasons are becoming more frequent and longer. The issue is therefore to allow people to keep in touch, communicate and play an active role in social life even if they are in various geographical locations.

The main tools for communicating with the outside (families, friends, and people sharing similar interest, one-to-few, few-to-one, one-to-many, many-to-one) are related to, or embedded in, or enabled by Internet and the World Wide Web. Since the early 1990s, the number of Internet users has increased drastically. In the developed countries Internet access point can be found basically in all homes/apartments. The access can be realized either in modem/telephone or in broadband connections (xDSL- and CATV-based technologies), which are increasingly prevalent. In early 2004 for example, 40% of the Western European households, had an Internet connection, of which 13% was a broadband connection (Bitkom, 2004). It is usually predicted that the price of broadband connections will be lowered considerably in

the future. This will again increase the use of Internet in homes for various purposes (games, education, work) and at all hours of the day. In the future, homes could become nodes in the World Wide Web, such as people are. Applications could be developed where houses can monitor other houses to increase safety, e.g. making an alarm when detecting a fire in a neighbouring house. This of course is a delicate topic touching on privacy and other related issues.

Communication tools have gained momentum in the form of shared limited access web pages for families, interest groups, etc. Some applications are specifically being developed for family or household uses. For example, the intelligent home will give information on the whereabouts and messages of family members and pets for all, e.g. via flat displays on walls or on the common information "desk": the door of the refrigerator. In a longer term, the aim would be to give access to everybody, anytime and anywhere to files or digitised documents, family calendar, photos, films created along his/her life, without being limited by user location, PC access and computer literacy. The challenge is to "deal with the stability of the past and the discontinuity of the present". This is the concept of "lifetime virtual boxes of souvenirs and memories", at different levels (personal, family or community) and with differentiated access rights. The family boxes may be passed to the next generations as a legacy.

Participation in the civil society takes different forms. Traditional participation in politics, union, religion can be enriched by e-consultations, voting or new forms of democratic consultations, referenda (e-government). New forms of participation such as involvement in human rights or environment NGOs, etc. would also benefit from e-participation. The local community life (sports, culture, education, events, etc.) would also be supported and enhanced by the new AmI technologies.

2.2.3. New forms of socialisation

Only half a century ago, people were socialising within close and pre-determined circles: neighbours, colleagues, clubs, etc. Nowadays, people travel and move more frequently, there are apparently many more possibilities to meet an increasing range of people (colleagues, neighbours, members of the same clubs, virtual buddies) the conditions to form a couple have become less rigid, the communication tools are becoming more sophisticated but the paradox is that the feeling of loneliness is always more widespread in cities, suburbs and villages in the countryside. In parallel the number of single people and single-parent families is steadily increasing.

The absurdity is that we are all the day long surrounded by crowds of people which at best constitute a huge waste of social capital (and at worst an implicit threat). City-dwellers pass everyday within a few meters of people who could give them a ride home, buy an item they are trying to sell, or consider them as potential friends or partners.

There is hence an urgent demand to enrich communication and community life through humanised technology, interactive environments in which people and autonomous systems can get in touch, establish a relation and co-operate in real time.

The vision is that the AmI technologies could change the paradigm of socialisation by putting seamlessly and unobtrusively people in contact on the basis of

comparable permanent patterns of interest or specific request. Dynamic networking makes it possible to tap those resources through a momentary alliance among transient interest groups, like people commuting to a certain district, needing a taxi to go to the airport, or sharing similar health concerns. Ad-hoc wireless social contacts or communities between like-minded or shared-interest strangers could therefore emerged spontaneously following negotiation of their respective virtual profiles.

2.3. Rest, refreshing, entertainment and sport

Albeit diverse, these functions are all very important. Some of them are performed mostly at home (resting), while others can also be performed outside (Entertainment & Hobbies).

2.3.1. Rest and relaxation

Sleeping can be considered as the most important form of the functions performed' at home as people spend 1/4 to 1/3 of a day in the bed. There were some interesting visions from the 1950s about peculiar electronic gadgets making bedroom electrically enhanced and also sleeping easy end enjoyable. Some low-tech electrical applications, electrically heated and vibrating blankets or beds, have found their niche in the market.

More recently, little in terms of high-tech applications has been developed to enhance or help the sleeping experience. This may be better this way as technological artefacts in this domain, such as the digital alarm clock, are mostly aiming at waking one up, even if they can now be set by a timer to give a softer wake-up through radio voice or music! It would certainly be appreciated it ambient intelligence applications could provide even more pleasant ways of waking up. Some scents of favourite flowers, movements of the bed, or beautiful scenery projected on the wall or ceiling could possibly be integrated to such a "wake up call".

More unobtrusive technologies could enable new applications. "Smart" system controlling air conditioning, lights and temperature in the bedroom may contribute to a more relaxing rest. Applications of ambient intelligence embedded in clock, bed, lamp, window, floor, ceiling, etc., could be supporting the sleeping process in its initial, midterm and terminal phase. They could also be linked with other systems, giving signals to other people in the house of sleeping persons in order to avoid disturbance.

Besides sleeping, there are various degrees of rest such as drowsing. It can also be done in other rooms than bedroom alone—lying on the couch in front of TV may be one of the most popular places to take a nap. The weather permitting, resting can be situated on balconies or terraces in the garden. Resting might be supported by ambient intelligence applications such as sensors embedded into the furniture measuring the resident's pulse, blood pressure and suggesting different kinds of electronic massage or acupuncture. Such massaging armchairs have already been in the market, especially Japanese, for at least two decades. However, intelligence could be added in the form of (bio)sensors, identifying the person sitting and his or her wishes.

2.3.2. Refreshing and hygiene

Another function mostly performed at home is concerned with the basic needs of the residents to refresh themselves and take care of their hygiene. This is an area where consumer electronics already abound. Ambient intelligence could be added to this array in the not-so-long-future. Bathing and showering space (tube, shower, sauna) could be equipped with ambient intelligence to identify the user and set the initial temperature of water, for instance, and play the background music expected.

Another trend is to optimise the time, which is anyway consumed in the bathroom for other functions. This is not new in itself as many people listen to radio in the bathroom and many hotels already have loudspeakers in the bathroom so that residents can hear, e.g. the news. Tooth brushing, combing, shaving, making-up, etc., usually takes place in the bathroom in front of the mirror and hence a bathroom mirror has been developed which not only reflects your image on its surface, but also displays the clock, news or the weather, or cartoons for the children. Similar applications can also display your weight and then report on your cardiovascular health, even giving advice on improvement (Peterson, 2002).

Another thing is, whether one does really want to be distracted while shaving with advises on how loosing weight or similar issues. They can be irritating, adding to the information overload and distracting from the main action thereby increasing the risk for mistakes or incidents.

2.3.3. Entertainment and hobbies

Ambient intelligence applications have a lot of potential to contribute to making in-house entertainment and hobbies a richer experience.

Radio, TV and music records have been the dominant entertainments in home environment for decades. All of these technologies have been developed towards digital format: music records in CD-format, video in DVD and there are already digital radio and TV-channels even if analogue broadcasting is still dominant in the latter cases. Music CDs and DVDs are the most popular articles in Internet-based marketplaces. Ordering and payment of product is currently done in Internet and only delivery of products still remains in the physical world. However, as the format of the content is digital, delivery via Internet (Video or Music on Demand) looks like a natural step to be taken.

Multimedia Entertainment (listening, watching, interacting) will slowly become available. The global trend is to enhance the experience of "passive entertainment" by providing more immersion and/or augmenting the engagement of the user. For example, devices turning home into a home theatre with sophisticated sound effects and possibly composing aids could support music as a hobby. Voice recognition could be combined with databases so that the dwellers can turn on the music simply by humming a few bars of a song (Peterson, 2002). If literature is your favourite hobby, details of the novel you are reading could be retrieved via Internet and displayed on the wall screen alongside with some related video clips. Interactive radio and TV programs allowing new forms of participating in broadcast programs could be diffused.

One of the challenges is to allow the user to define him/herself the right balance between relatively passive enjoyment of multimedia entertainment and interactive engagement in programs and to offer him/her a switching modes between them. The user does not want to loose control over time, place and mode of entertainment.

Computer and console games have been an increasingly popular form of entertainment and are major drivers for the development of ICTs. There already are computer games for most of the popular movies and characters (e.g. Harry Potter).

The trends are to increase the realism and to add to the excitement of with collective gaming, mobile gaming and immersive experiences. There have been networked computer games for some time already (MUD = Multi User Dungeon) and it is likely that the same trend will take over in game consoles. Earlier mobile gaming consoles were single game consoles, and then they developed to mobile game platforms with possibility to have different games in memory card. Lately, gaming has become an important addition to functionality of mobile phones. There are even mobile terminals optimised in mobile gaming (e.g. Nokia N-gage). With advanced mobile technologies, the pervasive gaming could be always on, always available. The virtual characters created by the gamers, might compete with each other around the clock with only occasional human intervention (Sleeth, 2002, p. 42).

However, one has to consider that this steadily improvement of video games and multimedia entertainment have serious drawbacks. Let us consider for instance that the average American children and teenagers already spend much more time and efforts watching TV and playing video games than school. Further social, physiological and medical studies on the effects of long-time immersion into fiction are needed as these effects are likely to be more alarming with future technologies (augmented reality with sound and 3D pictures, ''increased-reality'' interfaces with feedback feeling, full-body interface or direct interface with the brain)?

2.3.4. Sport and fitness

Physical exercises are important for mental and physical well-being. Within the home, physical exercise can be made in space reserved especially for it, possibly using electronic exercise bikes or rowing machines. The market also offers wearable exercise equipment that demand no effort from its user, for example vibrating the muscles it is attached to.

A future trend might be to integrate physical exercise capacities into ''ordinary'' furniture, placed in living room, bedroom or even kitchen. This idea of multifunction, flexible furniture is already implicit, although without any intelligence, in modern housing where the home is required to fulfil many functions in the same space such as leisure, work and hobbies. Ambient intelligence devices would monitor the resident if he/she wants to know, e.g. the minutes used in stepping the stairs or walking inside the house and equivalent of consumed calories.

However, an over-intensive practise may be dangerous for senior and/or irregular sport(wo)men. The issue is to reduce the risks and to optimise the time devoted to sport and fitness practise in a modern society. Accordingly, there is a demand for ambient-intelligence applications, which recognises and monitors the resident's state of health, need of physical exercise and remembers previous sessions, experiences

and results, suggesting optimal procedures. A dedicated "Sport and Fitness Assistant" could include the functions of health (ECG, blood pressure) and performance monitoring (instantaneous and average speeds, distance).

2.4. Working and learning

Home is increasingly expected to provide premises for working and learning. The work done at home naturally includes household and maintenance work, but also other professional work which is traditionally done elsewhere. The functions of work supported by ICTs and other new technologies in connection to housing (household, maintenance and home office work) are frequently addressed in the literature.

2.4.1. Household work

Household work aims at keeping the house as an adequate and comfortable place to live in and maintaining the welfare of the occupants. Household work is here considered as a large domain, encompassing basic activities such as cleaning, laundering, cooking and preparing meals, washing up, sewing, etc.

Definitively, technological artefacts have over the last half-century made many household tasks much easier and further technological developments would be much needed to relieve the burden of household. However, these applications also have had unexpected and social implications and the global outcome may not be so straightforward. A good illustration is the case of the washing machine.

> "The Washing machine was pitched as a labour saving device, and even though initial models did not go through a cycle automatically or spin-dry, they did reduce the labour of wash day. However, washing machines arrived around the same time as a host of other devices, including hot water heaters, irons and indoor bathrooms. All of these technologies in concert changed users' expectations of "acceptable" hygiene and washing: with so many consequences, why limit yourself to washing yourself and your clothes once a week? ... Over time, these devices changed society's expectations about what things would be done, how often and by whom. Indeed studies of domestic technologies so not show conclusively that work was reduced; more significantly, some suggest that amount of unpaid work in the home done by women rose dramatically." (Edwards and Grinter, 2001)

Washing machines are indeed the main technological tools for cleaning and taking care of clothes and all kinds of linen used in housing. Other related machines are drying machines, sewing machines, etc. Today, they already contain microprocessors and a variety of programmes. Ambient intelligence could mean that the machines themselves could conclude from the degree of dirtiness the need for a certain programme, e.g. in a washing machine.

Cleaning the house could be facilitated by more efficient vacuum cleaners and eventually cleaning robots with sensors for turning when facing obstacles. Ambient intelligence would be needed for the cleaning robots to discern small items on the floor and to tell the difference between a trash such as a bottle cap and valuables such

as a diamond ring, for instance. Ambient intelligence will proceed when self-cleaning surfaces can be integrated in the house. In the longer term, the need for cleaning many objects or environments will disappear as the cleaning function will be embedded directly into them as an own intrinsic property.

Cooking and preparing meals is at the same time a very basic and routine function and an important happening—a process involving socialisation with family, friends and relatives. The process begins with preparing the meal, having the meal and cleaning up. Ambient intelligence could be applied to establishing a database of guests' food preferences, allergies, previous catering, etc., suggesting menus. In cooking, the oven could become aware of the degree and need of cooking time for a given portion of food and regulate its heat. In robotics, prototypes of serving robots, pouring drinks for example have been developed. Tables could have surfaces, which know which dishes have to be kept warm or cold. The kitchen is already now the heart of home, in a sense that life-sustaining food preparation takes place there. In addition, it is a communication centre where the refrigerator wall often abounds in notes from family members (shopping lists, messages and appointments). The refrigerator could become a kitchen computer displaying information and evaluating its own contents and missing ingredients. Such technological developments are already under way but the products already on the market are not encountering a huge success as people undoubtedly prefer the human touch.

2.4.2. Maintenance work

Maintenance work aims at providing the living conditions adequate and comfortable in the premises by maintaining and upgrading the "welfare" of the building. In analogy with future applications of ambient intelligence in the form of self-cleaning surface, self-repairing elements of the house could be developed. Walls, floor and the ceiling could monitor themselves and start repairing themselves or at least warn about the situation. When painting on the surfaces wears off, it could be replenished.

Also gardening can be included in household work covering the work around the house. Lawn mowing robot has already been developed. What would then make such household robots more developed towards ambient intelligence? Perhaps the capacity to detect a need for lawn mowing would be such. In the far future still lies the prototype of a lawnmower, which would detect flowers to be preserved on its working area.

Changes in weather conditions may be a trigger to activate certain maintenance functions in the house. For example rain together with temperature close to freezing point may activate a doorstep heater outside the house or more importantly switch on the heating within the greenhouse.

2.4.3. Home office work

The professional life is traditionally conducted elsewhere outside of home (at office or at clients' premises, etc.), but new trends in teleworking and the increasing pressure put on many executives create new demands in terms of making the home compatible with professional activities. Such work can be for example home-based overtime work: people taking work from office home with them to be done in the

evening. Work could be altogether located at home, such as free-lancer or subcontracted work. Another category of work done at home is e-work or telework, characterised as substituting the work done at office. Thus, overtime work is not telework, although the nature of carrying out the work is the same. e-work is transferred by telepresence and concrete ICT applications from elsewhere to home. The work performed at home is often knowledge-based and involving a variety of ICT equipment and installations. It is now increasingly integrated into normal housing functions and even also embedded among other functions.

However, the professional life may consist in other kind of activities, artistic for instance. Home is also a place for learning. Children do their homework in their rooms or elsewhere in the home, but adult members of a household can also make some studies and need a place for learning. A common denominator is that these functions require space and equipment. Usually a fixed space inside the home is dedicated to this activity, but it could be transferable into other locations inside home. This space can be called a home office—home with an embedded office. Housing makes its own demands. The workspace should be flexible, convertible and not-much-space-consuming. The computers will have to move from the desk to the wall and be equipped with speech-recognition technology. This applies not just to home-located work, but to all other functions as well. Halal (2003) calls this new conversational human-machine dialogue as Teleliving.

The division between work and leisure has been blurred. However, there is a growing demand of keeping these two functions apart, while enabling them both at the same place (home). This is because work located inside the home may cause unnecessary stress by the simple visual existence of the home office. Applications of ambient intelligence could be integrated into the furniture and walls. Space for e-work has certain requirements and especially the ICT equipment and installations need to be located with a minimum hindrance to daily routines in housing. The space, furniture and installations for e-work are suitable for all the other teleactivities as well. Therefore, there is a demand for applying ambient intelligence to make such space and work functions as comfortable and discrete as possible.

3. Conclusion

The idea of a future home equipped with technical devices that reduce burdens and make life easier is an old one. What is new with ambient intelligence in this idea, is the added value of transparency and interactivity. As Aarts and Marzano (2003) put it, paradoxically the home of tomorrow will look more like the home of yesterday than the home of today. The bulky technological devices will fade into the background and be embedded into surfaces and ornaments.

There are great opportunities for ambient intelligence in housing: people spend a lot of time in their homes and both social and technological drivers are broadening the scope of activities to be undertaken at home. Solutions similar to the ones already developed for cars can be applied to housing. Consumer electronics, by having already gained a strong foothold in housing, can be at the forefront of ambient intelligence.

However, there are some critical aspects and serious challenges concerning the development of ambient intelligence in the field of housing. Home is a sanctuary, so technology and technological devices integrated to the house should not dominate the overall function of housing. The technology should enhance the quality if life of residents, not only by facilitating their daily activities, but also supporting their socialisation. Another major challenge for ambient intelligence is how to make technology learn about the people and their identity: habits, preferences, behavioral patterns, etc. and how to apply such knowledge in varying contexts. Such situational awareness should be promoted simultaneously securing a sufficient degree of privacy and prevention against misuse. The more complex the systems become, the more vulnerable they are to malfunction.

Also ethical and philosophical concerns are striking. It is certainly not desirable to aim at a full automation of the home with ambient-intelligence applications. In a critical essay, Araya (Araya, 1995) describes the marginality of the enhancement proposed (e.g. elevator stops at right floor, rooms greet people by name, automatic coffee, etc.) as a fundamental character of ubiquitous computing. If the relevance appears too marginal compared to the investments required to access the new functions and if the intrinsic risks of the technologies are too high, then even the well-educated and well-off people may refuse innovations in specific fields. If initiative or physical movement is no longer needed, the passivating implications for the elderly, especially, might prove deteriorating to one's physical and mental health. Ambient intelligence should not pretend to go away from the fundamentally embodied/emplaced nature of the human life by promoting an extreme dematerialisation of the body. The challenge is to provide high-quality technological life-enhancing "housing-aids" and at the same time safety, stimulation and socialisation for the elderly (see e.g. op den Akker, 2004).

Moreover, research on use and acceptance demonstrates that even if innovative functions are accessible to people, there is no inherent guarantee that they will actually accept and use them (Punie, 2003). Past unforeseen market failures (e.g. videotext, Video on Demand, WAP) and successes are well known. Short Message Services (SMS) (Stock, 2002) is an interesting example of the latter, not only because its success surprised many experts, but also because of its function. Sending text messages via the mobile phone may first appeared marginal but finally encountered a huge market. It is difficult to foresee which functions in the future Ambient Intelligence environments will provide the trigger for reaching a critical mass of users. People make use of new technologies in ways that are very different from their intended uses by suppliers (e.g. the Internet, SMS), there is no typical, uniform user and use but rather a diversity of users and uses. Suppliers generally have difficulties in understanding the user market in a qualitative way (Punie, 2005).

Successful innovation is the result of a specific socio-economic and technological constellation, i.e. the right product, on the right market, at the right time and in the right combination where specific requirements in terms of user needs, user-friendliness, price, attractive supply, standards, interoperability, and so on have to be met. If they are not, the commercialization will certainly fail. However, failed attempts may ultimately emerge as successful, perhaps in new guises, when the right conditions are in place (Miles et al., 2002).

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