AMBIENT INTELLIGENCE
Paving the way... Edited by John Gill
Ambient Intelligence is where people are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognising and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way.

Ducatel K, et al. Scenarios for Ambient Intelligence 2010
AMBIENT INTELLIGENCE

Paving the way . . . How integrated services can deliver a more inclusive society

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In sheltered accommodation each room can have responsive monitoring systems that provide the occupant with information, guidance and feedback.

Feedback can be given on simple items such as windows left open or doors left unlocked.

Danger areas such as kitchens can be monitored.

Public transport could transmit information to a person's home, enabling travellers to accurately plan their journey. The driver could also be made aware of a person's special needs.

Sensors can be programmed to provide feedback to carers; for example if medicines have not been taken.

Information can be sent to remote carers.
The evolution from an industrial society to an information society holds many promises and challenges: it stimulates the creation of services and the acceleration of knowledge-sharing and encourages broad universal participation. Distinctions based on national or regional borders, social status, opinion, religion, race or language appear to be disappearing: the information society draws everyone closer together.

However, this new society only really includes those who know about it and are in a position to participate in it. If nothing is done, there is a risk that the information society will exclude large numbers of Europeans, more than one in three, whilst entrenching serious and profound inequalities which may ultimately become irreversible. A lot of work remains to be done to overcome digital divides. It is only natural that Europe should promote an information society that is accessible to all by laying solid foundations for e-accessibility. Accessibility of the information society is a key priority. We cannot afford to leave so many citizens behind and lose the potential societal and economic benefits of their full inclusion in the information society.

The information and knowledge channels are multiplying and evolving faster than could ever have been imagined. The production of information and knowledge is becoming increasingly decentralized as each of us is getting involved in the process with growing autonomy. Hence, in this digital era, we need a reference framework, improved rules and structures to ensure that the production and the spread of knowledge and information are accessible to all and may be completed and enhanced by everyone.

Europe actively supports the development of full website accessibility and is encouraging industries to produce user-friendly and standardised electronic devices, accessible digital television, total conversation telecommunications. We also need to get the content right - inclusive public services, subtitling and audio description in programmes, digital competence. The European Union is promoting on-line content developed in a way which secures access for people with disabilities when they surf the internet or watch television and also strongly supports research by funding innovative projects to facilitate the integration of certain groups at risk of exclusion such as people with disabilities, elderly people, people with lower education or lower income.

A horizontal approach to inclusion is being adopted. It seeks to mainstream e-inclusion goals across all relevant policies, improving cooperation and monitoring progress.

When it comes to promoting an information society for all, the European Commission is only one of the actors. We know that the most important results are achieved through cooperation - with stakeholders, Member States and the industry, by sharing good practices, not forgetting the importance of action at local level, close to the intended beneficiaries, in their immediate social context.

An information society that is accessible to all is a societal and economic imperative. With its approach and actions, Europe is contributing actively to its creation.

Viviane Reding
Member of the European Commission, responsible for Information Society and Media
Society is undergoing a fundamental transition, from the present industrial society towards an information society. Among the possible embodiments of the emerging information society, an interesting and widely discussed potential instantiation is the Ambient Intelligence (AmI) paradigm. The information society is not seen as being characterised by an increased diffusion and use of present-day computers and telecommunication terminals, but as the emergence of an environment in which people are surrounded by fixed and mobile intelligent objects, interconnected through fixed and mobile networks, and an environment capable of recognising and responding to the presence of different individuals. The interaction with the objects and with the intelligence in the environment will allow access to information, interpersonal communication and environmental control.

The AmI environment will be populated by a multitude of hand-held and wearable ‘micro-devices’ and computational power and interaction peripherals (eg embedded screens and speakers, ambient displays) will be distributed in the environment. Devices will range from ‘personal’ (eg wrist-watches, bracelets, personal mobile displays and notification systems, health monitors embedded in clothing), carrying individual and possibly private information, to ‘public’ in the surrounding environment (eg wall-mounted displays). As technology ‘disappears’ to humans both physically and mentally, devices will be no longer perceived as computers, but rather as augmented elements of the physical environment. Personal devices will be equipped with facilities for multimodal interaction and alternative input/output (eg voice recognition and synthesis, pen-based pointing devices, vibration alerting, touch screens, input prediction), or with accessories that facilitate alternative ways of use (eg hands-free kits), thus addressing a wider range of user and context requirements than the traditional desktop computer.

A variety of new products and services will be made possible by the emerging technological environment, including home networking and automation, mobile health management, interpersonal communication, and personalised information services. These applications will be characterised by increasing ubiquity, nomadism and personalisation, and are likely to pervade all daily human activities. They will have the potential to enhance security in the physical environment, save human time, augment human memory and support people in daily routines and simple activities, as well as in complex tasks.

What are Ambient Intelligent Systems?

How integrated services can deliver a more inclusive society
This development is potentially very promising for users. According to European development scenarios, from a socio-economic perspective ambient intelligence is supposed:

- to facilitate human contacts;
- to be oriented towards community and cultural enhancement;
- to help to build knowledge and skills for work, better quality of work, citizenship and consumer choice;
- to inspire trust and confidence;
- to be consistent with long-term sustainability - personal, societal and environmental - and with life-long learning;
- to be controllable by ordinary people. Moreover, from a human-computer interaction perspective, interaction with the intelligent environment will have to be redefined.

Namely, the ambient intelligence environment must be unobtrusive (ie many distributed devices are embedded in the environment, and do not intrude into our consciousness unless we need them), personalized (ie it can recognize the user, and its behaviour can be tailored to the user’s needs), adaptive (ie its behaviour can change in response to a person’s actions and environment), and anticipatory (ie it anticipates a person’s desires and environment as much as possible without the need for mediation). Therefore, the emphasis is put on greater user-friendliness, more efficient support of services, user-empowerment, and support for human interaction. Interaction is intended as taking place through ‘natural’ interfaces.

However, integration within the AmI environment is complex, due to the interplay of its different levels, eg the physical level with a multiplicity and heterogeneity of intelligent objects and their need for a continuous and high-speed connection, the level of identification and consideration of the variety of contexts of use, and the level of elicitation of the diversity of user goals and help in their fulfilment. The system must be able to seamlessly integrate the three levels considered above. At the lower level, all intelligent objects in the environment must be interconnected and able to cooperate in order to support the goals of the user. Moreover, the environment must be reconfigurable in real time, to cater for the introduction or removal of components (for example, objects that users entering the environment may have with them). At a higher level, the AmI environment must take care of the contexts of use considered as processes, which are defined by specific sets of situations, roles, relations, and entities.

In the foreseen ubiquitous interaction with information and telecommunication systems the context of use may change continuously or abruptly and the same systems or services may need to behave differently in different contexts. Finally, it must be considered that most of the interaction with currently available systems is based on the performance of tasks determined by the application used. In the intelligent environment, the goals of the user are the starting point. They must be inferred by the system and decomposed into tasks that are adapted to the preferences of the individual. Therefore, the environment must not only be filled with intelligent objects (that is, computer-based systems), but must also be able to reason with regard to the goals of the users.

Therefore the acceptability and uptake of the new paradigm will be dependent on a design that facilitates the system in inferring the goals of the users in the continuously varying contexts of use and in organising the available resources in order to help users to fulfil them in a psychologically acceptable way. From this perspective, for example, the system must be able to deal with the task of inferring the goals of the users without giving them the impression that they are under control (big brother), and must be able to support the users without giving them the impression that they are forcing them. It must ‘offer’ possible solutions, not ‘impose’ them. This requires a lot of ingenuity also on the part of human beings, and appears particularly difficult for a machine.

| Approximate proportion of the population who have disabilities which are likely to affect their use of ambient intelligent systems (NB Do not aggregate the figures since multiple impairments are common) |
|----------------|-----------------------------|
| 0.4% | Wheelchair users |
| 5.0% | Cannot walk without an aid |
| 2.8% | Reduced strength |
| 1.4% | Reduced co-ordination |
| 0.3% | Speech impaired |
| 0.6% | Language impaired |
| 1.0% | Dyslexic |
| 3.0% | Intellectually impaired |
| 0.1% | Deaf |
| 6.0% | Hard of hearing |
| 0.4% | Blind |
| 1.5% | Low vision |
From a technological perspective, challenges are present from many perspectives: the real availability of the foreseen technology, its integration in a working system, the interaction with the emerging environment, and the acceptability of the resulting services by the potential users.

In the European ISTAG documents, the following ‘key enabling technologies’ are considered as a basis for the emergence of an intelligent environment:

- embedded intelligence,
- middleware and distributed systems,
- IP mobile and wireless,
- multi-domain network management,
- converging core and access networks,
- micro and opto-electronics,
- trust and confidence enabling tools,
- cross-media content,
- multi-modal and adaptive interfaces,
- multi-lingual dialogue mode.

Some of them may be of paramount interest for the inclusion of all citizens.

Moreover, the following requirements are considered crucial for the technological developments. The first is that the hardware must be very unobtrusive. Many technologies are conceived as hand-held or wearable, taking advantage of the intelligence embedded in the environment. This means being lightweight, but also available. People will have with them everything they need to perform any tasks. For example, the only foreseen communication item (sufficient for carrying out navigation, environmental control, and communication) is a personal communicator (P-Com). It has disembodied functionality supported by AmI with different interfaces. It is adaptive, and learns from user’s interactions. It is not necessarily a highly sophisticated piece of equipment; the performance will be limited by size, weight, and power.

A personal communication device can be worn or fitted to a wheelchair or a blind person’s cane. These can be programmed to communicate with barriers, ticket machines and gates to allow access or more time.

Smart tags, embedded in a floor, can receive and send information that will guide a person to a destination. A person with low-vision could hear guidance signals.
The necessary intelligence can be in the environment and the only limiting factor can be the bandwidth. This hardware must be integrated in a seamless mobile/fixed web-based communications infrastructure. Complex heterogeneous mobile and fixed networks need to interoperate and to be dynamically reconfigurable. This will allow the deployment of dynamic and massively distributed device networks. The AmI landscape is a world in which there are almost uncountable interoperating devices (wire, wireless, mobile, and fixed).

Interactions must be through natural human interfaces and with systems that are intuitive in use. This will need artificial intelligence techniques as the basis for intelligent agents and human to machine interactions, which are supposed to be multimodal (multi-user, multilingual, multi-channel and multipurpose), context sensitive and able to filter information. Finally, a very important design requirement is dependability and security. The AmI-world must be safe, dependable and secure, considering all physical and psychological threats that the technologies might imply.

**Basic Technologies**

One of the main prerequisites of AmI is that interactions must be multimodal. In principle, the different modalities can be used concurrently so as to increase the quantity of available information or, alternatively, to present the same information in different contexts, or, redundantly, to address different interaction channels. Inclusive design is instrumental in deciding how to use multimodality for different users in different contexts and for setting the design goals. Voice synthesis and recognition can be considered as an example. For recognition, the technological goal is the recognition of connected speech in noisy environments, allowing the production of efficient inputs for people who cannot use keyboards or object manipulation techniques. However, the training system must be robust enough to accept also voices of people with cerebral palsy. Correspondingly, voice synthesis needs not only to achieve better quality, but also to incorporate personal characteristics for the implementation of speech prostheses.

Another design target is the development of automatic translation for real-time conversation between people speaking different languages. Automatic translation has the potential of eliminating the barrier among different countries but the level of integration will depend on the languages that are considered. Different sign languages and symbolic languages, such as Bliss, must be part of the considered set.

Special vibrating materials for alerting people will increase the efficiency of alarm systems for people who cannot use auditory signals. These developments are also related to the study of materials capable of sensing touch or producing three-dimensional tactile presentations of information.

Global positioning systems (GPS) are likely to become standard in many devices and services. This will solve the problem of tracing people and will help in navigation (e.g., for people who cannot see). However, to be useful in all environments, GPS localisation should be integrated by the deployment of networks of sensors in closed spaces.

Smart tags can signal the presence of objects and provide detailed information about them. For example, a person who cannot see could be directly informed about the items on the shelves of a supermarket. At home, the same person could be able to locate small objects, such as a box of pills or spectacles, and have information about the medication and the dosage. The pill box could also be authorised to make the person aware of its presence.

Gesture recognition can be used to implement virtual keyboards and pointing devices, and to produce interfaces for the manipulation of objects on the screen. Traditional switches could become virtual switches. Interfaces based on the recognition of lip movements or sign-language could also be conceived. Correspondingly, animation technology could be used to produce avatars able to sign or to move lips for lip reading.

Visualisation technologies are considered of paramount importance. Screens should be available everywhere. New materials will produce screens that are lightweight and foldable and follow the user (nomadicity and availability). Alternatively, the presentation screen could be virtual, using projection systems, and the presentation of 3-D information should be possible.
The environment as a general facilitator

Some interesting conclusions can be drawn with reference to services available in the environment (e.g., airport, hotel, city, cafeteria). First of all, the entire AmI is a pervasive and very sophisticated environmental control, alarm and support/control system.

Then, relay services for people who cannot hear and/or speak may be available by default in the AmI environment, if voice recognition and synthesis, automatic translation, gesture recognition (sign language and lip reading) and animation (synthetic sign language and lip movements) are made available.

However, the real winning factor is in intelligence. To plan her business travels, Ann (the generic ISTAG character) relies on agents that can look for relevant information and negotiate on her behalf. Her agents negotiate for a rented car at a reduced price and to obtain a discounted permit to enter the city. Another agent helps her in localising her business presentation according to local preferences (colour schemes, the use of language). These possibilities can be crucial for people who have hearing or speech problems impeding interpersonal communication or sight and manipulation problems reducing efficiency in accessing information. The possibility of delegating transactions can also be crucial if Ann is an older person with cognitive limitations.

When arriving at her destination, if Ann is not able to see, the P-Com guides her through the airport (e.g., by voice, or using haptic cues). This requires knowledge of her position in the airport and the possibility of controlling the presence of obstacles (people, baggage, etc) through a control system able to monitor tagged objects. If Ann has cognitive limitations, the navigation system may tune the level of support to her known abilities or to the perceived present difficulties. In the hotel, if Ann cannot see, AmI is able to describe the layout and functionalities of the room, as well as the functionalities of its devices (e.g., the remote control). Its functions can be simplified according to her characteristics and preferences.

When moving in the city AmI registers Ann as a client who cannot see and suggests routes and paths that are not too busy. Alternatively, if AmI registers Ann as an older client, it can connect with the control centre to verify whether she may be allowed to travel alone on
the metro or she must be assisted. The level of support can be tuned to Ann’s capabilities (probably changing in time). If Ann is moving around in a wheelchair, AmI can suggest an accessible route to her destination.

At home, if Ann has cognitive limitations, she may need guidance through the required actions. With mild cognitive problems, AmI can remind and provide suggestions, just like a friend. With more severe problems, AmI can completely control the situation: preparing a balanced diet, checking the availability of food, ordering it, caring for its delivery at home, and suggesting all the steps necessary for its preparation. This can be done autonomously or in cooperation with a relative or carer.

Additional opportunities offered by AmI are related to the availability of broadband communication facilities. In the hotel room there is an audio/video system, whose video scenes are described if Ann cannot see and automatically captioned if she cannot hear. The system can be used also for communication with her daughter. The fact that Ann and her daughter are able to converse and cooperatively access information, is very important. It introduces a remote socialisation component, which can be crucial to reduce stress, and through which Ann can be supported not by technology but by another person. If Ann has cognitive problems, her daughter can instruct her when performing tasks. In this case the advantage is reciprocal, because the daughter can monitor that everything is ok without being too intrusive.

The individual interacting with the environment

It is interesting to discuss how all the characters in the scenarios can interact with the multimodal AmI. If an inclusive design approach has been used, for example if Ann is not able to see, she can receive audio messages. If she is not able to speak at all, she can use gesture recognition or text, and if she is not able to speak perfectly the voice recognition system can be trained to match the characteristics of the produced audio signal. If she is not able to hear she can receive text or sign messages.

At the same time, interaction will shift from an explicit paradigm, in which the users’ attention is on tasks, towards an implicit paradigm, in which interfaces themselves proactively drive human attention when required according to their goals. Humans will leave the execution of single tasks to intelligent computing units. Task delegation may be anticipated to significantly alleviate both the physical and the cognitive efforts required for interaction.

The user perspective

Many other aspects of the development of an intelligent environment will have impact on the population at large and on people with disabilities in particular. First of all, it is necessary to investigate how human functions will be engaged in the emerging forms of interaction and how this interaction will affect individual perceptive and cognitive spaces. The emerging environment will be very complex and stimulating, from both a sensorial and cognitive perspective. It is not clear whether people will be able to cope with the hyper-stimulation and the corresponding cognitive load. This is particularly true for people with reduced abilities, and principally for people with cognitive limitations.

Therefore, environment must be developed in such a way that the relevant social factors and the capabilities of people are taken into account, for example, in order to balance the distribution of tasks between the user and the intelligent environment itself.

To be really useful AmI must be reliable, continuously available in space and time, consistent in its functionalities and interactions in private and (crowded and potentially hazardous) public spaces. This may be a very difficult task, due to the inherent complexity of the system.
For older people living independently, ambient intelligent systems offer the possibility to support their independence as well as promoting social contact and reducing isolation. Services could also be delivered when the user wants them, rather than the current system of what fits in with the scheduling of the service provider. The systems could also learn to predict the user’s needs as well as providing safety monitoring (e.g., giving a warning if the cooker has been left on).

Current smart home technology is mostly developed from a technological point of view. Therefore the big challenge is to change this process. This not only requires changes from developers but also from all users involved. Developers need to be able to translate user requirements into technological ideas and concepts. Users that aren’t used to playing a role in the design process are suddenly asked for input on the possible role of technology in their life and their requirements for that technology.

For individuals requiring a greater degree of support the system could be set to provide rapid response to changes in medical or social care conditions of the individual. This will require health care organisations to have the appropriate technology as well as the willingness to use it. Also implied is greater communication between various people providing care which may include informal carers as well as professional organisations.

The system could monitor the user’s health and offer appropriate levels of medication in addition to advising the health care organisation of the situation. Such systems are unlikely to cope with a user who picks up a tablet from the container but does not take it. So there must be systems in place to back up any automated service with periodic checks by a medical practitioner.

If a condition of living independently is that the user has an AmI system, then provision should be made for users to be fully aware of what information about them and their activities is available to other people. The problem of informed consent is exacerbated if the user has deteriorating mental capabilities.
Ethical and Privacy Issues

One of the great benefits of ambient intelligence is its versatility, and the many uses that the same information can have in interacting with indoor and outdoor environments. However this versatility is also a potential weakness, as in order for ambient intelligence to work, information must be shared over multiple networks. This means that data must be made available through a central database to other ‘trusted’ networks, or that data must be replicated across multiple databases. If data is replicated, then the accuracy of the information could come into question, as the information would need to be constantly updated across networks.

Ambient intelligence requires users to ‘trust’ the information technology systems around them. It is this trust that is the root of many of the potential difficulties. As everyone is aware, computers will do exactly as they are instructed, including implementing errors. Because of this danger, one question that must be asked is what can we trust these systems to do? If a system is relied upon to open doors automatically, systems need to be put in place to ensure that there are other means of carrying out this function. If there is an automatic emergency function, can it be guaranteed that it will work when required? And on what basis does it make the ‘decision’ to call? If an attempt at contact is made, and the person’s own electronic device refuses to allow contact, on what basis does it do this?

Also, if the system is set up for someone with disabilities, decisions are being made in some cases for people, and this in itself is an ethical issue. Procedures need to be put in place to ensure that if possible the person contributes to the making of these decisions, and if this is not possible that the decisions made are really in the interests of the end user affected.

There are potential problems caused by unauthorised access to the system. Ambient intelligence works through the use of wireless technology, meaning that information has to be broadcast. A worrying possibility is that someone may breach the security system, capture these details, and use them elsewhere. Careful design of the system becomes essential.

Guidelines are needed to ensure that all automatic ‘decisions’ made by the system have been approved by the end user, and these decisions are made available to be reviewed at regular intervals. This would allow problems to be detected and corrected.

Adherence to data protection guidelines needs to be made explicit in the development of ambient intelligence systems. This would mean that a ‘specified explicit purpose’ can be agreed upon, that only the relevant information is stored or transmitted by the system. A regular review of the information needs to be built in, to ensure that information about a person is accurate, and to give the person an opportunity to request the removal of information from the system.
Delivering Ambient Intelligent Services to Users with Disabilities

The key to delivering ambient intelligence to users is being able to provide what is wanted, when, where and how it is wanted. All aspects are important so that the user receives the right information, at the right time and in the right way so the person can make use of this information. However user control is paramount so they can decide what information they want and whether or not they want to receive it at any given point.

Users must not have to understand the technology to use it and most will have no desire to think about it. Information should be delivered to the users on their own existing devices (such as a mobile phone). Therefore interfaces must be straightforward and meaningful without the user being overwhelmed by options and menus. Ambient intelligent systems must be intuitive and easy to use so that the individual can interact with the services without effort.

The involvement of users throughout the design and development of services and products cannot be over emphasised. It is vital that ideas and concepts are tested as well as prototypes and the final product. As a rule users are not always aware of the products and services they will take up until they have experienced them. User testing and evaluation centred on real life implementation rather than conceptual technology driven ideas are the key to achieving products and services that meet real user needs.

A tourist carrying heavy suitcases visiting a city will have different needs once checked in, and exploring the sights. A working mother will want to interact with ambient intelligent systems at different levels when meeting business clients or navigating public transport with young children and shopping. These examples share a common theme – that of changing requirements as a result of changing circumstances. A truly intelligent agent/environment will remember all previous preferences as well as deriving new information based on what appears to be a change in behaviour. This will form part of an evolving preference storing system which tracks a user’s decisions over time to make a more informed choice at the next stage. It will make intelligent ‘guesses’ about what is needed and when it is needed as a personal friend would.

So will individuals embrace ambient intelligence? An intelligent service will only be used if it is seen to be of benefit without effort and with no risk of compromising privacy. This will require resources to be devoted to educating people with disabilities about the possibilities and limitations of various ambient intelligent systems.

However a service will need to be provided to help people with disabilities identify which options will best meet their individual needs, configure systems to be usable by that individual, and provide training and support in the use of these services.
Further Information

COST - the acronym for European Cooperation in the field of Scientific and Technical Research - is the oldest and widest European intergovernmental network for cooperation in research. Established by the Ministerial Conference in November 1971, COST is presently used by the scientific communities of 35 European countries to cooperate in common research projects supported by national funds.

The funds provided by COST - less than 1% of the total value of the projects - support the COST cooperation networks (COST Actions). With 30 million Euros per year, more than 30,000 European scientists are involved in research having a total value which exceeds 2 billion Euros per year. This is the financial worth of the European added value which COST achieves.

A ‘bottom up approach’ (the initiative of launching a COST Action comes from the European scientists themselves), ‘à la carte participation’ (only countries interested in the Action participate), ‘equality of access’ (participation is open also to the scientific communities of countries not belonging to the European Union) and ‘flexible structure’ (easy implementation and light management of the research initiatives) are the main characteristics of COST.

As precursor of advanced multidisciplinary research COST has a very important role for the realisation of the European Research Area anticipating and complementing the activities of the Framework Programmes, constituting a ‘bridge’ towards the scientific communities of emerging countries, increasing the mobility of researchers across Europe and fostering the establishment of ‘Networks of Excellence’ in many key scientific domains such as: Biomedicine and Molecular Biosciences; Food and Agriculture; Forests, their Products and Services; Materials, Physical and Nanosciences; Chemistry and Molecular Sciences and Technologies; Earth System Science and Environmental Management; Information and Communication Technologies; Transport and Urban Development; Individuals, Societies, Cultures and Health. It covers basic and more applied research and also addresses issues of pre-normative nature or of societal importance.

Further information: www.cost.esf.org

COST 219ter

The main objective of this Action is to increase the accessibility of next generation telecommunication network services and equipment to elderly people and people with disabilities by design or, alternatively, by adaptation when required.

Further information: www.tiresias.org/cost219ter

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Ambient intelligent systems offer exciting possibilities for helping people with disabilities

Consistent adaptive, or adaptable, user interfaces are essential

Ethical guidelines appropriate to people with disabilities should be agreed before services come into use

Support services for people with disabilities need to be established