Ambient Intelligence: Invisible Electronics Emerging

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Abstract

Ambient Intelligence is a novel paradigm in consumer electronics that refers to smart electronic environments that can enhance peoples' lives. We briefly discuss the underlying vision and the developments that support it, with an emphasis on planar technologies.

Introduction

Ambient intelligence refers to electronic environments that are aware of and responsive to the presence of people [1]. Ambient systems are thought to consist of many distributed consumer devices that interact with users in a natural way. The concept builds on the early ideas of *ubiquitous computing* introduced by the late Marc Weiser [13] and anticipates a digital world in which electronic devices have entirely vanished into people's background. In this respect it is comparable to other efforts with similar objectives such as MIT's *Oxygen* project [3] and IBM's effort on *pervasive computing* [9]. Compared to these, ambient intelligence focuses on the user and the user experience from a consumer electronics perspective, which introduces several new basic problems related to natural user interaction and ubiquitous consumer architectures supporting information, communication, and entertainment. A good overview of these issues can be found in the special issue on ambient intelligence of ECRIM News [5].

Ambient Intelligent Environments

In an ambient intelligent environment people will be surrounded by networked systems of intelligent devices that provide information, communication services and entertainment wherever we are. Furthermore, the devices will adapt and even anticipate our needs. Ambient intelligent environments will present themselves in a very different way than our contemporary handheld or stationary electronic boxes as they will merge in a natural way into the environment around us and as they will allow much more natural and human interaction styles. Electronics will be integrated into our clothing, furniture, cars, houses, offices, and public places. From a technological point of view this has become feasible, as we will argue below, but from a user point of view there are still many issues that need to be addressed with respect to usability and appreciability. Before we elaborate on this let's have a look at the following scenario, which describes an ambient intelligent world that enhances the life of the people that live in it.

The shape of things to come

Returning home late after a days work, Tom approaches his front door where he is recognized by the 3D animated dog Bello that appears tail wagging on the front door, which is also a flat display. After authentication the door alerts that it is open by changing its color. Tom enters the hall where he can see in a single glance on the ambient home flow management system that his daughter Kathy is out with friends, that there are a few new messages, and that the domestic robot Dusty is cleaning the living. Dusty approaches him when he enters the living and through a single phrase he sends Dusty off to the kitchen to continue its work there. He walks to the interactive table and starts handling his messages through a combination of touch and speech control. One of the massages indicates that the shopping list composed by the intelligent larder needs confirmation before it is sent to the e-supermarket. It also lists a range of menus that can be cooked with the food that is currently in the larder. Another message tells him that the home information system has located the information he requested about affordable holiday cottages with sea views in Spain. A glow tag in the photo frame on the buffet indicates that Kathy, who in the mean time has been notified by her private communicator that dad is home, want to contact Tom when he is available. Tom asks the home communicator to contact Kathy, and after a few seconds her image appears on a display in the window screen. After a chat with Kathy Tom starts browsing in his personalized video systems using a touch pad integrated into the armrest of his chair. After some time Tom decides to stop video browsing and switches the window screens to the life sunset at the beach of the Café del Mar while listening to their music.

Visions leading to Ambient Intelligence

As of the introduction of consumer electronics people have been dreaming of intelligent and ambient devices. At the 1958 World's Fair in Brussels Philips presented a media pavilion designed by the famous architect Le Corbusier. The pavilion's futuristic exterior expressed the technological advance of mankind. The interior was left empty to expose the spectators to the ultimate experience of *Le Poeme Electronique",* a presentation of ambient light, color, sound, voice and moving images orchestrated by Le Corbusier and the composer Edgar Varèse, which

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according to Treib [12] is now recognized as the first immersive multimedia show. Other examples of early ambient intelligent systems are shown in science fiction movies. Well-known examples are Stanley Kubrick's *2001: A Space Odyssey*, a classic movie from the 1960s in which an intelligent electronic world is depicted with humanlike characteristics. In *Total Recall* Paul Verhoeven envisions a digitally controlled world with large interactive screens and holographic images. Albert Brocolli uses in many of his James Bond movies examples of intelligent electronic devices integrated into ordinary objects.

Related developments

During the 1990s computer scientists like Weiser [13] have been developing the concept of *ubiquitous computing* as a successor paradigm to mobile computing. It describes a world in which computing devices are as ubiquitous as electric power outlets and electric light devices that were once rare and exciting. In this concept, people are surrounded with dozens if not thousands of networked embedded systems. These supply control, navigation support through information, or worldwide access to communication or entertainment services. This concept is generally seen as the third generation of computing systems after the mainframes and personal computers, and can be seen as an extension of today's Internet with much smaller personal and portable web access devices, even beyond the current mobile phones and personal digital assistants. In an attempt to enhance the office professionals' productivity with a factor three, Dertouzos of MIT has started the ambitious Oxygen project [3]. To fulfill this ambition heterogeneous networks, portable and stationary systems must be developed that can considerably reduce the time to interact, search and deal with information. As this brings more time to people, by applying the same techniques to entertainment and life support, the quality of this extra time and of life itself can be enhanced. Already today, distant health monitoring services for people with potential cardiac failures are emerging, supplying continuously vital real time information analysis to clients.

A second theme by Dertouzos focuses on human centric computing in which after 50 years, computers have to adapt to humans in stead of the other way around [4]. This requires the designer to place the user in the middle of the digital environment instead of the instruction format. Ambient intelligence aims to achieve human centric computing by making people's environments intelligent and by applying a natural and social user interface. The interface technologies are selected to represent natural multi-modal interfaces credible to the human brain and social to the extent that the system will adapt to the intuition and habits of the human user. Reeves and Nass [8] have shown that it is relatively easy to get the human brain to accept man-machine interaction as natural, probably due to the slow evolutionary development of the brain. The ability to adapt itself to the user is determined by the system's capability to learn from previous interactions. Combinations of machine vision, speech recognition, language interpretation, query and search techniques and language synthesis, together with handwriting, tactile input and gesture recognition play a crucial role in the design of new ways of interaction.

Driving forces

Major driving forces towards the Ambient Intelligence paradigm are the development of miniaturization technologies, the advent of the experience economy, and societal human needs to stay electronically connected to their business partners, family, and friends.

Technology. The developments in electronics follow Moore's law, which state that the integration density of systems on silicon doubles every 18 months. With some deviations and many ups and downs, the silicon industry has followed this path for 40 years now and there seem to be at least another 12 years ahead. Moreover, other parameters such as bandwidth of communication systems, storage capacity on magnetic and optical disks, and cost per bit of I/O processing follow similar steep improvement curves at constant environmental impact. This is due to planar technologies such as used in Integrated Circuits manufacturing or flat screen Liquid Crystal Devices. Many of these technologies have found applications to make the interaction between man and machine easier, more effective and more enjoyable. Especially speech recognition and synthesis is expected to further revolutionize electronics and bring even more intimate and natural interaction. Additionally wireless, wired and glass fiber networks span the globe to give access to anyone at anytime to anything imaginable. Compression schemes such as MPEG2, 4 and 7 allow digital distribution of high quality audio, video and data e.g., using internet transport Protocols or recordable video disks.

Economy. In a recent book Pine and Gilmore [7] introduce a new economy that they call the *experience economy*. This economy is to be positioned as the fourth wave after the classical economies of the commodities, goods and services. The idea is based on Mazlow's hierarchy of needs. Customers attribute the highest value to an economic transaction if it is accompanied by the feeling of a true experience. Pine and Gilmore argue that people in the new economy will be inclined to spend large amounts of money to have experiences. The holiday economy is an example of such behavior. We argue that consumer electronics can contribute significantly to the user experience. A simple example is the home cinema. More generally speaking, recollection of memorabilia of personal events, through digital still pictures, video recordings, sound recordings, music possibly in combination with the use of graspable interfaces based on electronic tokens and

tagged objects that can make everything look intelligent will enable people to have unlimited amounts of digital experiences [11].

Society. The needs of a sustainable society and the opportunities offered by ambient intelligence provide solutions to many of the social, cultural, and intellectual needs of people. Many studies into socio-cultural trends have revealed that the basic needs of people are to *stay in touch* and to *stay in control.* There is a drive within society to develop a *new modernity* in which people are positioned in the centers of their own little universes from which they can communicate with any other desired person. In this light the interaction between the needs of a sustainable society and the possibilities offered by ambient intelligence can be seen as an alliance that can give rise to an age in which we can continue to believe in progress based on quality rather than on quantity. The design of ambient intelligent systems, services, and experiences in the new modernity is an artistic process that should be based on a human centered approach in which the technology is used to enhance peoples' lives. Marzano [6] calls this the age of *ambient culture* and in his vision of the future he describes a wealth of new applications in domestic, mobile, personal, and productivity environments.

Planar technologies

Few technologies other than planar silicon IC technology had so much impact over the past fifty years on the development and production of new electronic systems and appliances. New and classical semi-conducting materials are applied to yield optimum solutions for special applications such as high frequency transceivers for wireless connectivity. Micro-electromechanical devices can be used for displays and switching with low impedance losses. Planar technologies span the signal conversion from external sensors and transducers with RF & mixed signal circuits to the digital world with digital signal processing and clever algorithms. At one end of the spectrum we find low data rate traffic with sensors and actuators of 1 bit/s – 250 kbps, at the other extreme where video is being transmitted we see 5 Gbit/s data rates. Especially, at the low data rate side, one can envisage dozens of devices, with low power, preferably drawn from the environment using solar cell action, with efficient bandwidth usage by means of multiple input and multiple output arrays, for low cost with 1- 2 mm^2 silicon area. These devices will be designed using dedicated techniques to deal especially with the efficiency and low power requirements. Also for the computational side of digital signal processing we see huge differences between control and the high end of media processing with 10 Mops for audio processing to 1 Tops for 3D synthetic video [2]. Combinations of silicon devices with Liquid Crystal Device layers on top yield very high performance projection display solutions for consumer applications such as high definition TV displays. These LCoS devices allow real life size projection in front or back projection systems that can be integrated completely into the furniture. On the other side of the range small color screens with video capability are appearing in mobile phones and PDAs. Even completely flexible displays based on semi-conducting polymers have recently been presented [10]. Both silicon and polymer identification tags and IC cards have been developed that allow electronic systems to keep track of goods, (micro) payments and complex logistics. A next development is the design of pico-radio devices: small sensor and actuator devices that can power themselves by making use of the physical changes of the environment in which they are positioned, like temperature or pressure changes. This makes it possible to put electronic tags into virtually any object thus introducing a basis for contextual and situational awareness. Furthermore, these solutions enable semi-intelligent systems that today let not very intelligent animals like cows to decide themselves whether they want to be milked or not. Apart from improving animal welfare this also relieves the farmer from having to milk his cows every day once or twice, thus providing him and his family with quality time, while the cow is having an experience.

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