AMBIENT INTELLIGENCE

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Abstract

This paper considers some history and the state of the art of Ambient Intelligence and from that seeks to identify new topics and future work. Ubiquitous computing, communications, human-centric computer interaction, embedded systems, context awareness, adaptive systems and distributed device networks are considered.

Keywords: Ambient intelligence, embedded systems, self-configuring, sensors, networks, ubiquitous comp*.

Introduction

Ambient intelligence is a vision of consumer electronics, telecommunications and computing that was originally developed in the late 1990s for the time frame 2010–2020. Although a little behind the USA (and MIT in particular), the Fifth European Framework Program began work in Europe in 2001. The IST Program Advisory Group of the European Commission (Directorate General on Information Society and the Media) introduced the concept of ambient intelligence by publishing a report titled "Scenarios for Ambient Intelligence in 2010" (Ducatel, 2001; Ducatel, 2003).

Ambient intelligence refers to a world, where devices work together to support people in easy, natural ways; using information and intelligence that is hidden in a self-configuring network of devices. These networks are usually wireless and self-configuring. As these interconnected devices grow smaller, more connected and more integrated into our environment, the technology disappears into our surroundings until only the user interface remains perceivable by users.

If objects were equipped with radio tags then they could be identified and managed by computers. Internet Protocol version 6 is a new Internet Layer protocol for packet-switched internetworks and for general use on the Internet. IPv6 has a much larger address space than the current IPv4, which provides flexibility in allocating addresses and routing traffic. The extended address length (128 bits) is intended to eliminate the need for network address translation to avoid address exhaustion, and also simplifies aspects of address assignment and renumbering, when changing Internet connectivity providers.

Internet Protocol version 6 will be able to identify more objects and will be able to instantaneously identify any kind of object. The Internet of objects could encode 100,000 billion objects and could follow the movement of those objects.

The ambient intelligence paradigm builds upon ubiquitous computing. At the moment, users consciously engage single devices for specific specialized purposes. Someone using ubiquitous computing engages many computational devices and systems simultaneously and may not necessarily even be aware that they are doing so. Ubiquitous computing is a post-desktop model of human-computer interaction in which information processing is integrated into objects and activities. This paradigm is described as ambient intelligence.

Human-centric computer interaction design needs systems and technologies that are: embedded (that is many networked devices are integrated into the environment); context aware (these devices can recognize you and your situational context); personalized (they can be tailored to specific needs); adaptive (they can change in response to you); and anticipatory (they can anticipate your desires without conscious mediation). These are each considered here.

Embedded. An embedded system is a special-purpose computer system designed to perform one (or a few) dedicated functions, often with real-time computing constraints. It is usually embedded as part of a complete device including hardware and mechanical parts. In contrast, a general-purpose computer can do many different tasks depending on programming. Since an embedded system is dedicated to specific tasks, design engineers can optimize it, reducing the size and cost of the product, or increasing the reliability and performance. Some embedded systems are mass-produced, benefiting from economies of scale. Physically, embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights or factory controllers. Complexity varies from low (with a single microcontroller chip) to high (with multiple units, peripherals and networks).

Context aware. Context awareness originated in computer science. It is a way of linking changes in the environment with computer systems. Although it originated in computer science, it has also been applied to business theory within business process management. In computer science it refers to the idea that computers can sense and react based on their environment. Devices may have information about the circumstances under which they are able to operate and based on rules, or an intelligent stimulus, react accordingly. The term context-awareness in ubiquitous computing was introduced by Schilit (1994a and 1994b). Context aware devices may also try to make assumptions about the user's current situation. Dey (2001) defined context as "any information that can be used to characterise the situation of entities. While the computer science community has initially perceived context as a matter of user location, this notion has been considered not simply as a state, but part of a process in which users are involved; thus, sophisticated and general context models have been proposed, to support context-aware applications which use them to adapt interfaces, tailor sets of application-relevant data, increase precision of information retrieval, discover services, make user-interaction implicit, or build smart environments. Context aware systems are concerned with the acquisition of context (that is using sensors to perceive a situation), the abstraction and understanding of context (that is matching a perceived sensory stimulus to a context) and application behaviour based on the recognized context (that is triggering actions based on context). Context awareness is regarded as an enabling technology for ubiquitous computing systems. Context awareness is used to design innovative user interfaces, and is often used as a part of ubiquitous computing. It is also beginning to be felt in the internet with the advent of hybrid search engines. Human factors related context is a subset of this area and is often structured into three categories: information on the user, the user's social environment, and the user's tasks. Likewise, context related to the physical environment is structured into three categories: location, infrastructure and physical conditions.

Personalized. Personalization is based on user attributes. Personalization models include rules-based filtering, based on if then rules (Sanders, 2001a), and collaborative filtering, which serves relevant material to customers by combining their own personal preferences with the preferences of like-minded others. Recently, another method, Prediction Based on Benefit is proposed for products with complex attributes such as apparel (Haag et al, 2006). Many companies already offer services for web recommendation and email recommendation that are based on personalization or anonymously collected user behaviours and some research is investigating Intelligent browser-based systems to assist Internet users (Bergasa-Suso, 2005) and electronic multi-media assessment systems (Chester, 2006). Web personalization is closely linked to the notion of adaptive hypermedia. The main difference is that the former would usually work on what is considered an Open Corpus Hypermedia, whilst the latter would traditionally work on Closed Corpus Hypermedia. However, recent research directions in the adaptive hypermedia domain take both closed and open corpus into account. Thus, the two fields are closely inter-related. Personalisation is also being considered for use in less overtly commercial applications to improve the user experience online.

Adaptive. An adaptive system is a set of interacting or interdependent entities, real or abstract, forming an integrated whole that together are able to respond to environmental changes or changes in the interacting parts.

Feedback loops represent a key feature of adaptive systems, allowing responses to changes; examples of adaptive systems include: natural ecosystems, individual organisms, human communities, human organizations, and human families. Some artificial systems can be adaptive as well; for instance, robots employ control systems that utilize feedback loops to sense new conditions in their environment and adapt accordingly (Stott, 1995). Adaptive behaviour is often characterized by a kind of behaviour that allows an individual to substitute an unconstructive or disruptive behaviour to something more constructive. These behaviours are most often social or personal behaviours. For example a constant repetitive action could be re-focused on something that creates or builds something. In other words the behaviour can be adapted to something else. A maladaptive behaviour is a behaviour or trait that is not adaptive (it might be counterproductive to the individual). Maladaptivity is frequently used as an indicator of abnormality or mental dysfunction in human beings, since its assessment is relatively free from subjectivity. However, much behaviour considered moral can be apparently maladaptive, such as dissent or abstinence.

Anticipatory. Anticipatory means that systems can anticipate desires without conscious mediation. For example, anticipatory scheduling is an algorithm for scheduling input/output. Anticipatory scheduling can yield significant improvements for some work. Another example is when a design program anticipates the next set of icons or buttons that a user might want to use and presents them to the user on the screen.

History

Early developments in Ambient Intelligence took place at Philips. In 1998, Philips commissioned a series of internal workshop to investigate different scenarios that would transform the high-volume consumer electronic industry from the current "fragmented-with-features" world into a world in 2020 where user-friendly devices support ubiquitous information, communication and entertainment. In 1999, Philips joined the Oxygen alliance, an international consortium of industrial partners within the MIT Oxygen project (Oxygen, 2006) aimed at developing technology for the computer of the 21st century. In 2000, plans were made to construct a feasibility and usability facility dedicated to Ambient Intelligence. This opened in 2002. Along with the build up of the vision for Philips, a parallel track was started to open up the vision. Following the advice of the Information Society and Technology Advisory Group, the European Commission used the vision for the launch of their sixth framework (FP5) in Information, Society and Technology and the Commission played a crucial role in further developing Ambient Intelligence. More recently, several major initiatives have been started in the USA, Canada, Spain, France and the Netherlands.

The future

Ambient intelligence emphasizes people and user experience. The interest in user experience grew in importance in the late 1990s because of the overload of products and services in the information society that were difficult to understand and hard to use. A strong call emerged to design things from a user's point of view. Ambient intelligence is influenced by user-centred design where the user is placed in the centre of the design activity and asked to give feedback through specific user evaluations and tests to improve the design or even co-create the design together with the designer or with other users. Ambient intelligence needs further development in a number of key technologies: Unobtrusive hardware; Seamless communication and computing infrastructure; Dynamic and distributed device networks; and human-centric computer interfaces. These are considered:

Unobtrusive hardware. The hardware needs development in miniaturisation, Nanotechnology, smart devices and sensors. Some projects in the 1950s from the space research program used smaller and smaller devices in the construction of rockets, satellites, guidance and telemetrical systems. Space stations needed to be light (yet rugged) and to have the ability to withstand wide variations in temperature, pressure, and stress. Research led to the development of new types of alloys that were notable for their lightness and toughness. One of the most important ideas derived from space technology was miniaturization which led to microminiaturization and sub miniaturization. In electronics, miniaturization was witnessed by an empirical observation called Moore's Law that predicted that the number of transistors on an integrated circuit for minimum component cost doubles every 24 months. Nanotechnology considers the control of matter on an atomic and molecular scale, generally dealing with structures of 100 nanometres or smaller. Nanotechnology is diverse, ranging from novel extensions of conventional devices, to completely new approaches based upon molecular self-assembly, to developing new materials with dimensions on the nanoscale. Nanotechnology does have the potential to create many new devices with wide-ranging applications but nanotechnology raises concerns about the toxicity and environmental impact of nano-materials (and their potential effects on global economics). These concerns have led to a debate among advocacy groups and governments on whether special regulation of nanotechnology is warranted.

Seamless communication and computing infrastructure. This needs interoperability, wired and wireless networks, service-oriented architecture and a semantic web. Interoperability refers to the ability of diverse systems and organizations to work together (inter-operate). In telecommunications, the term can be defined as: the ability of systems, units, or forces to provide services to and accept services from other systems, units or forces and to use the services exchanged to enable them to operate effectively together – or - the condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases. In two-way radio, interoperability is composed of three dimensions: compatible communications paths (compatible frequencies, equipment and signalling), radio system coverage or adequate signal strength, and scalable capacity. With respect to software, the term interoperability is used to describe the capability of different programs to exchange data via a common set of exchange formats, to read and write the same file formats, and to use the same protocols. The ideal is the ability to execute the same binary code on different microprocessors. Interoperability does need some standardization but the aim is to be able to communicate, execute programs, or transfer data

among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units. In computing, service-oriented architecture provides methods for systems development and integration where systems group functionality around business processes and package these as interoperable services. Service-orientation aims at a loose coupling of services with operating systems, programming languages and other technologies which underlie applications. Service-oriented architecture separates functions into distinct units (or services), which developers make accessible over a network in order that users can combine and reuse them in the production of business applications (Thomas, 2005). These services communicate with each other by passing data from one service to another, or by coordinating an activity between two or more services.

Dynamic and massively distributed device networks. Distributed device networks are needed that are easy to control and program. Auto-configuration devices can automatically configure themselves without manual intervention and without any need for software configuration programs. Auto-configuring devices just plug-and-play, for example the Universal Serial Bus standard to interface devices to a host computer allows many peripherals to be connected using a single standardized interface socket and allows hot-swapping to allow devices to be connected and disconnected without rebooting the computer or turning off the device. In addition, power is provided to low-consumption devices. The Universal Serial Bus was originally designed for personal computers, but it has become commonplace on other devices such as PDAs and video game consoles, and as a bridging power cord between a device and an AC adapter plugged into a wall plug for charging purposes. Auto configuration has become possible because of the low cost of embedded controllers. In some cases, hot pluggable devices may be able to renegotiate their configuration. Service discovery protocols will allow automatic detection of devices and services on a computer network.

Human-centric computer interfaces. These interfaces need intelligent agents, multimodal interaction and context awareness. An intelligent agent is an entity which observes and acts upon an environment and directs its activity towards achieving goals. Intelligent agents may also learn or use knowledge to achieve their goals. Intelligent agents are often described schematically as an abstract functional system similar to a computer program. For this reason, intelligent agents are sometimes called abstract intelligent agents to distinguish them from their real world implementations as computer systems, biological systems, or organizations. Abstract intelligent agents exhibit an essence of human-like intelligence and may have numerous other properties resulting from the properties of its carrier physical or software system (Gadomski, 1995). Some definitions of intelligent agents emphasize their autonomy, and so prefer the term autonomous intelligent agents. Others considered goal-directed behaviour as the essence of rationality and so preferred the term rational agent (Russell & Norvig, 2003). Intelligent agents are related to software agents (an autonomous software program that assists users). In computer science, the term intelligent agent may be used to refer to a software agent that has some intelligence, for example, autonomous programs used for operator assistance or data mining are called intelligent agents (Bergasa-suso, 2005). Multimodal interaction provides the user with multiple modes of interfacing with a system beyond the traditional keyboard and mouse input/output. The most common such interface combines a visual modality (for example display, keyboard and mouse) with speech recognition and speech synthesis. However others are possible, such as pen-based input (Sanders, 2005) or haptic input/output (Sanders, 2001). An advantage of multiple modalities is increased usability in that the weaknesses of one modality can be offset by the strengths of another. Multimodal user interfaces also have implications for accessibility (Vitense, 2002).

Discussion, conclusions and future work.

For the moment, ambient intelligence is mainly about interactions between human beings and their environment. The environment can be seen as just another intelligent agent that is able to interact with users and other agents... creating processes to interpret, inform, communicate and dialogue (Abowd & Mynatt, 2000; Remagnino & Foresti, 2005).

Initially work may concentrate on niche markets in industrial, commercial or public applications where better interfaces may help to improve human performance. After that, ways for ambient intelligence to facilitate human contact, community and cultural enhancement need to be investigated. It should help to build knowledge and skills for work and better quality of work. Further development requires competences from computer vision, machine learning, distributed computing, context awareness systems and sensor networks. Finally, devices need to be self-testing and to have self repairing software. They need to be private and secure.

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