Ambient Intelligence in Perspective

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INTRODUCTION

Ambient intelligence (AmI) is a relatively new and distinct interpretation of the mobile computing paradigm. However, its recognition that embedded intelligence, either in actuality or perception, is an essential prerequisite if mobile computing is to realize its potential distinguishes it from other mobile usage paradigms. Though stressing the need for intelligence, and implicitly the adoption of artificial intelligence (AI) techniques, AmI does not formally ratify any particular approach and is thus technique agnostic. In this article, we examine the constituent technologies of AmI and provide a brief overview of some exemplary AmI projects. In particular, the question of intelligence is considered and some strategies for incorporating intelligence into AmI applications and services are proposed. It is the authors hope that a mature understanding of the issues involved will aid software professionals in the design and implementation of AmI applications.

BACKGROUND

In 2001, the EU Information Society Technologies Advisory Group (ISTAG) launched a report that proceeded to define the term Ambient Intelligence (ISTAG, 2001). Over a decade earlier, the late Mark Weiser had defined his vision for ubiquitous computing (Weiser, 1991). This vision was far ahead of its time but has been perceived by computer scientists as a vision worth pursuing. As the various technological hurdles were being progressively overcome, ISTAG recognised the inevitability of ubiquitous, pervasive technologies being widely deployed. In practice, this would mean entire generations growing, learning, working and relaxing in an environment saturated with smart sensors and other embedded artifacts. However, a key problem was identified: how to facilitate intuitive interaction with the prevailing embedded technologies. In particular, the scale of these interactions could potentially give rise to situations where numerous artifacts would be clamouring for the individual's attention. Given that human attention is a scarce and precious resource, this course of action could have undesired consequences, and a situation could be envisaged arising where a user might perceive environments saturated with embedded technologies as being places best avoided. Hence, the objective of AmI is to facilitate seamless intuitive interaction between users and their environment.

CONSTITUENT TECHNOLOGIES FOR AMBIENT INTELLIGENCE

Ambient intelligence (AmI) (Aarts & Marzano, 2003; Vasilakos & Pedrycz, 2006) has evolved conceptually and practically, resulting in a common agreement on its core constituent technologies. Three technologies have been identified as being essential to AmI: ubiquitous computing, ubiquitous communications and intelligent user interfaces.

Ubiquitous Computing

Ubiquitous computing envisages the embedding of computational artifacts in the physical environment and their subsequent intuitive access by users. Concerned with the prominence of the then current range of computing systems and their unwieldy interaction modalities, Weiser hoped that ubiquitous computing would herald in an era of what he termed *calm technology*. However, before this could take place, significant advances would have to take place in a number of computing disciplines. One area of particular interest is that of smart environments, as such environments seek to deliver a practical realisation of the ubiquitous computing vision in everyday scenarios, including the home and office. Integration of microprocessors into people's everyday living space objects, such as furniture, clothing, toys and so on, allows the immediate living space to become sensitive and responsive to its inhabitants, rather than just remaining inanimate. Hence, the origin of the term ubiquitous, which implies that something exists or is everywhere within a living environment on a constant level. A concept closely associated with ubiquitous computing is that of context (Dourish, 2004). In ubiquitous computing, and indeed, other computer usage paradigms, it is envisaged that a model of the user and their environment is available, thus enabling the delivery of services to users that have been dynamically adapted according to the user's current context. Here, context may entail such factors as temporal information, elements of their individual profile (sex, languages spoken, etc.) and current location. In the latter case, absolute positioning, for example, geographic coordinates, or relative positioning, for example, west of a certain landmark, could be used, depending on the nature of the service in question. From a software perspective, the continuous process of capturing context and interpreting it is computationally expensive, and significant scope exists for incorporating intelligent techniques. Such techniques may be used to incorporate reasoning about incomplete knowledge, or perhaps infer future user behavior based on past experiences.

Ubiquitous Communications

Computing technology is increasingly pervasive in everyday life, though under a number of guises, for example, cellular phones and standard embedded household electronics. With continually decreasing hardware costs, relentless miniaturisation and the adoption of high speed data networks, this trend is likely to continue. For example, modern automobiles already contain dozens of microprocessors, while the increasing popularity of Third Generation (3G) mobile phones means that mobile computing is now within reach of people in all facets of their daily lives. Indeed, the widespread deployment of wireless technologies has ensured that mobile computing is spawning a dominant new culture (Rheingold, 2002), as encounters with people using their cellular phones, PDAs, MP3 players, digital cameras and so on is a regular occurrence. Traditionally, these islands of technology would have existed in isolation. However, AmI takes a more holistic view and demands that the existence of a multiprotocol communications infrastructure for integrating disparate technologies such that a unison between all electronic data and equipment pertinent to the user's immediate context can be achieved. Thus, ubiquitous communications seeks to enable embedded objects to communicate with each other and the user by means of various fixed, wireless and ad-hoc networking techniques.

Intelligent User Interfaces

Intelligent user interfaces (IUIs) form the third, and arguably the most important, component of AmI. Human attention is a precious resource. Thus, it must be used judiciously when available, and should be requested cautiously and prudently. It is this prominence given to the need for new innovative interface technologies that distinguishes AmI from other mobile computing paradigms, and also motivates the need for intelligence. The urgent need for IUIs is seen when the nature of the AmI environment is considered. A multitude of embedded or smart artifacts all competing for explicit user attention does not constitute a usable system. Thus, for the sanity of the user, alternative techniques must be considered. Three issues are of particular interest: the need for new physical interface technologies, support for more sophisticated interaction modalities, and the need for collaboration between the constituent components of the environment such that intelligent behaviour can be utilised to the maximum.

Traditional graphical user interfaces (GUIs) are well understood from an ergonomic and implementation perspective. Such GUIs comprise devices such as a keyboard, mouse, and visual display unit; however, at present, the large ambient space that surrounds the user is unused. Thus, AmI demands more sophisticated interaction modalities that utilises this space but which may be difficult to implement and interpret. Examples of such modalities include voice, handwriting, gestures and gaze. The situation is exacerbated when it is considered that a mixture of modalities, for example, voice and gesture, may be used. Interpreting these modalities may require the availability of significant computational resources which may give rise to serious difficulty. A complementary strategy may involve the deployment of embedded dedicated sensors that aid the AmI environment monitor the user, develop sophisticated behaviour models, and enables it to proactively pre-empt user requests. However, no single interaction modality or interface technology can achieve this on its own. Rather, a degree of collaboration and intelligence is necessary to harness and interpret the data before a decision can be made as to whether an explicit interaction session with the user should be initiated.

REALIZING PRACTICAL AMBIENT INTELLIGENT ENVIRONMENTS

A number of organisations, in an effort to understand how AmI environments would work in practice, have designed and developed realistic test environments in which AmI scenarios can be quickly prototyped and evaluated. Philips HomeLab (Aarts & Eggen, 2002), launched in 2002, is one well known example. In essence this lab is a real home, modeled on a two level, two bedroom home. Volunteers live in this house 24 hours a day and their interactions with various electronic devices are observed by researchers. In this way, it is hoped to gain a deeper understanding of how people interact with technology in the home, resulting in

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