Ambient Intelligence

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ABSTRACT

Ambient intelligence (AmI) refers to the concept of embedding technology in the environment that is then used to assist and support the people using it. The environment component supports the "ambient" part of the description, but there is also the "intelligence" part; which deals with the variety of sensors in a network communicating with each other to carry out high level tasks requested by the user. The aim of this paradigm is to minimise the use of a specific terminal to facilitate user interaction with a system, and integrate it seamlessly into the user's life. The idea is to make the technology as intuitive and as easy-to-use as possible without disrupting the user's activity.

In this paper, the usability requirements of employing AmI systems in a domestic environment will be explored. This will include delving into a few studies that explore aspects of making this paradigm work, as well as specially constructed research areas that employ an AmI system. Each of these studies discuss what should be expected of an AmI system, and what this means for deployment of the paradigm as a whole.

Author Keywords

Ambient intelligence; activity theory; context-awareness; MavHome, iDorm; Ambient Wall; localisation; presence detection; Next Generation Ambient Intelligent Environments;

INTRODUCTION

Ambient intelligence (AmI) refers to the concept of embedding technology in the environment that is then used to assist and support the people using it. There are numerous definitions of AmI in the field of research, most involving the following attributes: it is sensitive, responsive, adaptive, transparent , ubiquitous and intelligent [2]. One of the defining quotes of the paradigm is one said by Mark Weiser in 1991: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it". The environment component supports the "ambient" part of the description, but there is also the "intelligence" part; which deals with the variety of sensors in a network communicating with each other to carry out high level tasks requested by the user. The aim of this paradigm is to minimise the use of a specific terminal to facilitate user interaction with a system, and integrate it seamlessly into the user's life. The idea is to make the technology as intuitive and as easy-to-use as possible without disrupting the user's activities.

There are many applications currently in development that feature the AmI paradigm. Such applications include intelligent homes, healthcare, assisted living, education, and marketing. Improving energy efficiency is also a very active field, which can be easily achieved by AmI systems by automatically turning off appliances that are not in use. A study using the iDorm is conducting research into this very area [5].

In this paper, the focus will be on the area of integrating it within domestic households, particularly the usability aspect. This is one of the larger areas that are currently under investigation to incorporate AmI. Two major problems that face the usability of AmI systems are: identifying context and responding appropriately, and determining the best interface for such a system in a home environment. These issues will be discussed in detail in the following sections. Current research studies into this area will also be briefly discussed. This includes a look into a new concept which can be used for context analysis, use of gesture based technology as an interface, evaluation of methods for localisation and presence detection, and looking into the specially constructed research environments MavHome and iDorm. To conclude, future work will also be briefly discussed; detailing the main shortcoming of current studies.

MAIN CHALLENGES

One of the biggest challenges is recognising what the users are doing and be able to support their actions. Details of this requirement are discussed in [2]. In order to support the "intelligence" part of the AmI paradigm, it is essential that the system is able to interpret the information it receives from all the sensors correctly and then execute the appropriate actions in a manner that is helpful to the user. For example, the system could play calming music when the user is feeling sad, but how would the system determine whether the user was feeling sad? User behaviour is usually erratic (especially to begin with) and it can be difficult for a

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system to gauge exactly what the user is doing, especially in a system with an ubiquitous interface. The more difficult aspect of this is the selection of an appropriate action by the system. This is difficult to determine because it is unknown how much system interference is appropriate. If the system interjects too frequently, it could result in a negative user experience with the system. Conversely, if the system does not aid enough, then it will not be of any real benefit for the user. An example of this is how reliable temperature moderating technology is. If the temperature is maintained at a satisfactory level for the user, then the user will not have to make explicit changes. However, if the changes made are not satisfactory, then the user will have to take corrective action, which undermines the purpose of the system. More dramatic consequences can be possible when applied to more serious aspects, such as household security and medical awareness. Inappropriate decision-making by the system can lead to major problems, such as the system making an emergency service call when one was not needed.

Relating to this problem, another challenge is determining what kind of interface is best for this application. Interaction with a main console breaks the flow of user activity, as the user has to stop what they are doing to directly interact with the system. It breaks the philosophy of the paradigm, so more natural ways of communicating with these systems are being sought out. Currently, natural language and gestures are being investigated as potential interfaces; each carrying with them their own challenges. Due to the variability of human speech, speech processing can be very challenging, especially when applied to a ubiquitous system. There are multiple speech patterns that can map to the same basic instruction for the system to carry out, and the system should be able to recognise them and carry out the correct action. For gesture-based interaction, it is difficult to determine what gestures are appropriate for each interaction. Ideally, the more dramatic the gesture is, the easier it is to detect, but it is also important that the gesture is intuitive and is easy for the user to conduct on a daily basis. The Ambient Wall [ambient wall] is one such project that incorporates gesture-based interaction. For both styles of interfaces; reliability and accuracy is key or user satisfaction will suffer as a result.

CURRENT STUDIES

There are a multitude of research projects that are currently at work to incorporate AmI into a domestic setting, as well as to enhance the effectiveness of the paradigm. Some of the research studies into improving the AmI paradigm for use within the household are detailed below.

Activity theory

Gauging a context and reacting appropriately is one of the fundamental aspects of AmI. Humans are very good at determining this, but it is very challenging for a system to know when to offer assistance or when to refrain. This continues to be one of the fundamental challenges in creating useful AmI decision making. Activity theory is one of the approaches to help deal with this problem, which is discussed extensively in [3]. It involves breaking down each activity to atomic components that a system can understand. Activity theory focuses on "the interaction of human activity and consciousness within its relevant environmental context" [3].

Activity theory is the means to formally describe the activities carried out by users on a daily basis. It consists of individuals (users), subjects (objects of interest) and the actions they carry out to achieve their goals.

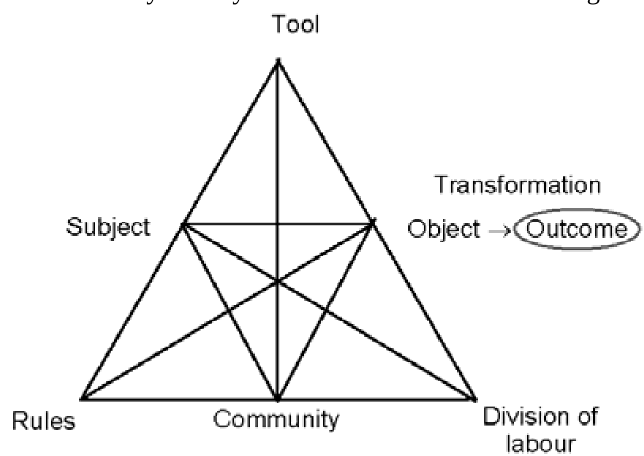

Figure 1: Basic structure of an activity [3]

These activities are dynamic and ever-changing, so it can be possible for the AmI system to break down these activities and adapt to any changes. As an activity develops, it creates contradictions within itself, which is resolved by developing that activity further into a further stage. This action also creates further contradictions, making this process ongoing. An activity is linked to an object where the goal is to transform the object using a set of tools. This identifies the context of the activity. The object can be a physical object or it can be more abstract, such as a plan to do something.

Using Activity Theory offers some benefits when using it with AmI systems: it formally structures an activity and its context, it supports the ever-changing nature of activities, and it provides a basic understanding of context to computer systems.

Ambient Wall

As previously mentioned, there is a lot of research going into the area of finding more natural ways of using this technology and more innovative ways to present the information to the user. Two such studies investigate new ways of presenting the information to the user. [4] describes the use of a unified interface within the home that is projected onto a blank wall (the "Ambient Wall") and controlled with hand gestures. In this interface, all information about the surrounding area can be accessed from a single interface, which can be displayed on a blank wall or ceiling.

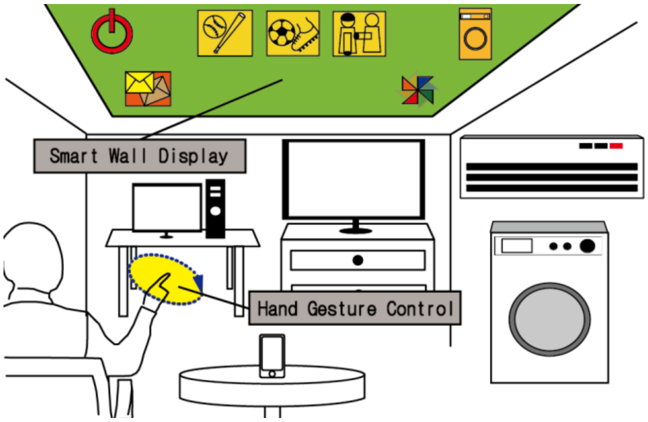

Figure 2: Ambient Wall Interface Concept [2]

The hand gestures used must be easily distinguishable from regularly used actions in order to be effective. Because the user does not normally point at the wall/ceiling, these gestures were suitable for this application. It was found that this type of interface was very effective for those with people who have difficulty moving their bodies without aid. This type of interface is moving towards a more ubiquitous and blending-in feel that AmI systems should have, and would be very effective if properly mastered.

Localization and presence detection

The other investigation mentioned ([5]) experiments with different types of technology to use to correctly localise an occupant in a room. The types of technologies used were 3D cameras (a Kinect sensor used in this experiment), microphones and PIR (widespread infrared) sensors. Three different scenarios were tested, which are viable behaviours for an AmI system to follow. The first consisted of two behaviours: a media presentation triggering when the occupant moved within proximity of the screen (50 centimetres in this experiment), and the volume of surrounding devices decreasing in volume when a participant was classified as being on the phone. The volume was decreased in proportion to the distance the participant was from that particular devices. The second scenario involved a 9 meter long walkway with panels connected to a PC positioned every 3 meters. As a participant walks passed the sensor, a presentation would play on that panel. As the participant moved away from the panel, the presentation would be stopped. The last scenario tested its multiple presence detection. Based on the number of people detected being in the room, the system would play different genres of music, varying the volume at each level. If there were 2 or less, then classical music would be played. As the number of occupants grew, then the genre would be changed from blues, rock, pop and house. If the room is empty, then no music would play.

It was found that the Kinect sensor was the most robust and accurate for presence detection at low distances. Microphone arrays were only practical if the occupant in the room is actively speaking, and there aren't multiple people speaking at the same time. PIR sensors largely depend on the quality of their lens, and are also dependant of the ambient temperature. If the ambient temperature is higher, then the difference with the human body temperature is lower, resulting in less accurate readings. Localisation and presence detection is a fundamental component of an effective AmI system, so it is important that the most effective sensors are chosen for each aspect.

Constructed Environments

In order to test AmI systems in a simulative environment, some research groups constructed their own ambient environments to carry out tests with living-in occupants. Two such projects include the MavHome project and the iDorm project, which will be discussed.

MavHome

The MavHome (Managing An Intelligent Versatile Home) is a project that is being carried out at the University of Texas in Arlington. The ambient technology used in this scenario is to maximise the efficiency of the various components within the house, as well as providing maximum comfort for the inhabitant. Efficiency is measured in terms of energy cost for gas and electricity, and comfort is judged according to the lighting, heating and ventilation of the environment. The main purposes of this project is to automate as much as possible without user intervention, and making the home more energy efficient. The whole house consists of sensors and agents that all communicate with each other. The agents are split into four layers: the Decision layer, the Communication layer, the Information layer and the Physical layer. The Decision layer decides what the correct course of action is based on the information it receives from the Information and Communication layers, which gathers sensory information from the Physical layer. The MavHome is able to learn the behaviour of its occupant via observation and data mining. This information is then used to build a model of the occupant's behaviour, which can then be used to predict actions [2]. If the action executed is not satisfactory to the user and is reversed, then the MavHome takes note of this for future situations. The data mining stage is essential for the system to be able to tailor its actions to the individual, and successfully perform meaningful interactions, fulfilling the "intelligence" aspect of the description. The MavHome components are being tested in two environments: a workplace environment and an on-campus apartment. Both these environments have different wants and needs from the occupants. In a conducted study, the MavHome was able to reduce the amount of user initiated daily interactions (manually turning the lights on, for example) by 76% [2]. The MavHome is a prime example of what can be possible with AmI systems in a domestic environment. The idea of taking predictive action is one that will be very beneficial if executed correctly.

iDorm

The iDorm (Intelligent Dormitory) is another AmI project that is being carried out at the University of Essex in the UK. The living space resembles that of a student dormitory and contains all the required furniture and equipment for sleeping, working and entertaining. The in-built sensors monitor the temperature, the humidity and occupant pose (lying down, sitting down, standing up, etc), and the effectors control the doors, the blinds and heating. [1] briefly describes how the environment functions. There are two major components that make up the iDorm structure: the embedded agent, which acts as a central hub for all the information, and the robot. The embedded agent receives all the information about the state of the dormitory and the occupant via all the sensors and executes the appropriate environment-based actions based on fuzzy logic. The robot is controlled by the embedded agent and can directly support the occupant. The iDorm has two types of control rules: static and dynamic. Static rules remain fixed regardless of who the user is. Examples of this are emergency protocols and powering down the iDorm if it is empty. Dynamic rules are rules generated depending on the user's preferences, such as temperature and lighting intensity. The dynamic rules are generated during the learning phase, in which the iDorm observes the user behaviour, similarly to that of the MavHome. The learning is based on negative reinforcement as well, tweaking the rule set as a user contradicts a change made by the environment. After the learning period, the embedded agent takes control of the room. If there are observed changes in the behaviour of the occupant, then the system reverts back to the learning phase. Similarly, if a new occupant enters the room, then the iDorm reverts to the learning phase to learn the new occupant's preferences. A total of 450 rules can be saved and retrieved at any time [1]. This adaptive behaviour is an ideal trait of AmI systems, and is a step towards a deployable system.

FUTURE WORK

There is a lot of potential to achieve revolutionary innovations in the field of AmI systems. Currently, the technology being tested in a household environment can only support one occupant. In many households, there are be multiple occupants so it is ideal that the system will be able to support them. Distinguishing between the individuals in the household will likely be the first step. Only then will the system be able to support each individual according to their own behaviours. Described as Next Generation Ambient Intelligent Environments (NGAIEs) in [6], the aim is to increase the number of objects connected to an area's network as well as increasing support for multiple occupants with the use of a concept known as the Activity Sphere. This alone can be a challenge due to the sheer amount of learning the system would have to do, making context awareness all the more crucial.

CONCLUSION

There have been many remarkable advances into turning AmI systems into a very achievable reality within the domestic environment. In order to stay true to the philosophy of the paradigm, new ways of using the system as well as teaching the system to understand humans are crucial parts in determining the success of the paradigm. In order for ambient intelligence to be useful for everyday life, it is essential that it does not disrupt routines and provides beneficial support to the user. Strides are being made in understanding how human behaviour works and how a computer system will be able to automate menial tasks and provide accurate assistance. It will only be a matter of time before these systems will be ready for real deployment. If the current progress is any indication, then this time will come sooner than anyone will expect.

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