

A Survey on Ambient Intelligence Projects

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Abstract — Intelligence is increasingly emerging in our ambients. Evidences of this emergence are the existence of smart homes, smart vehicles, intelligent manufacturing systems and most importantly, in the appearance of the concept of intelligent cities. Humans are presently surrounded by technology that is intended to increase their quality of life and simplify their daily activities. Multi-Agent Systems are examples of the technology that can be used in these activities. The concept of ubiquitous computing is implicit in these technologies and can generate an invisible ambient of interactivity. This paper presents a survey and a comparative analysis of some of the research projects concerning Ambient Intelligence (AmI). The main objective of this work was to understand the current necessities, devices and the main results in the development of these projects. By analysing these projects using several evaluation criteria one of the main conclusions is that most projects do not explore the potential of human profiles in the context of ambient adaptation. Thus, this may be a very interesting research area for future work.

Keywords - ambient intelligence; multi-agent systems; ubiquitous computing; human-computer interaction; profiling.

I. INTRODUCTION

A. Context

Humans have increasingly felt the necessity of well-being and comfort wherever they might be located. How does the surrounding ambient contribute to human comfort? With the evolution of technology it is possible to adapt the ambient to humans.

In these ambients, which are entitled of Intelligent Ambients by the scientific community, there is a perception of the human presence and of their behaviour through technologies (smart devices and interfaces) implanted around the humans. Several technological solutions have emerged with the purpose of approaching the concept of interactivity with the existing reality in these ambients reacting to human stimuli in an invisible way [1].

This work presents a survey on some of the most relevant Ambient Intelligence projects, with a specific focus on the human profile, which is a crucial aspect to take into account when searching for a correct response to the human stimuli.

B. Motivation

Ambient Intelligence systems can be explored in two important perspectives: the analysis of human profiles and the capabilities of devices used in these ambients. Exploring the first perspective can lead to more efficient and personalized

forms of relationship, with other people in the ambient, and thus improve the quality of life. However, many of these forms are not yet adequately explored in terms of human profiles as can be verified later in the projects' analysis.

Exploring the second perspective may enhance the development of technology as an easier way to create interaction [2].

These systems have forms of interaction between people and technology, making it suitable for the necessities of individuals and surrounding ambients [3], as for example: motion sensors, output sensors in households, speech recognition sensors, etc. This technology aims to improve the quality of life and facilitate people's daily lives. However it is questionable if these interactions are sufficient to create a more pleasant ambient to humans and consequently following questions arise: Does the ambient interact with people? Does the ambient understand the feelings, tastes, preferences and necessities of the person? Is the person a passive or an active element of this ambient? How is the adaptation of the in ambient where people have different tastes?

II. RELATED WORK

This section presents an overview of the state of the art on the area of Ambient Intelligence.

A. Ambient Intelligence (AmI)

The ISTAG, European Commission's IST Advisory Group, which produced a report providing the main orientations for ICT research in Europe, created the term Ambient Intelligence [4][5]. This commission believed in that not only the development of technology as support for interactivity should be considered, but that it is also essential to take a broader view on innovations that can be developed in these ambients, from their creation until they reach the end user - people [6].

The evolution of Ambient Intelligence made other concepts to emerge, having a great importance to the development of new technologies used in these ambients. One of these concepts is Ubiquitous Computing and it was created by Mark Weiser in 1991 [7]. Ubiquitous Computing means having access to technology devices in several spaces to make Human-Computer Interaction (HCI) invisible [8]. In other words, it integrates informatics and technologies with the natural actions and the behaviour of humans anywhere [9].

The adaptation, in AmI systems, of these technologies to human necessities is performed by Ubiquitous Computing [10]. It creates an interaction between these two elements

(technologies - humans), that should be carried out in such a way that people do not realize that they are giving commands to a computer, but instead they interact as if they were communicating with someone.

The scientific community that investigates Human-Computer Interaction is sensible to the importance that the context may have in Intelligent Ambients. This context is identified as any information that can be used to describe a situation of an entity, which may be a person, object or ambient [13]. The recognition of such information is essential to decide acting intelligently in this context [8].

To facilitate these decisions, technologies must recognize the stimuli created between the ambient and humans [11] and the information obtained from this process should be treated by intelligent technologies and personalized automatically to make available a proper interaction. These intelligent technologies must be in constant development and improvement, in order to keep up with a research subject that increasingly acquired more importance in everyday life [12].

B. Agents in AmI

In Ambient Intelligence the life cycle starts by a tracking service for the acquisition of information about the human and the ambient that surrounds it, based on sensors. Then an information manager analyzes and processes the information, giving consistency to the data and stores them. After this process, activities to be performed are defined and the users that will be affected are identified. Decisions are communicated to devices to perform the relevant actions and to humans via their ambient. Humans can modify their behaviour at any time during the process and create circumstances that influence the context [10].

As mentioned previously, context information is important to define the interaction of persons with the technology which surrounds them and has been implemented in the ambient, so it is necessary to perform a continuous control of information relating to people and their environment [14].

Agents and Multi-Agent Systems (MAS) are two of the technologies typically used in Ambient Intelligence contexts.

An agent is identified as a computer system located in an ambient with competence to act autonomously in this ambient to achieve certain objectives [15]. If we analyze the previous definition in a more comprehensive way, an agent is anything that is competent to understand its environment based on its sensors' information, to understand the actions of humans, react through its actuators, possibly modifying the ambient, and learn from the experience [16].

A MAS is understood as any system composed of several autonomous agents with unfinished features to resolve a global problem, where there is no overall control system, the data is not centralized and computation is asynchronous [15] [17]. This group of agents has to combine their expertise and cooperate in order to satisfy a common objective [9].

The agents include these main characteristics [15] [18]:

- Reasoning - the agents must act rationally with the purpose of achieving its objectives for a given evaluation function;
- Autonomy - without human intervention, the agents can function and take control of their state and actions;
- Reactivity – agents must have the perception of their surroundings and respond to the environmental changes;
- Socialization – agents must be able to foster interactions with other agents and eventually persons;
- Pro-activity – agents may act in advance in order to take the initiative of action instead of just reacting to the environment and external stimuli;
- Temporal continuity – agents should perform active or inactive processes continually;
- Object-oriented – agents should use a structured approach to handle complex tasks.

These main characteristics are what make the agents able to deal with the improvement of dynamic and dispersed systems based on intelligent ambient. Because agents have the capacity to adjust to the features of the ambient and the behaviors of people placed in context, they can also apply mechanisms of reasoning and understanding with the objective of learning from experience [10] [19].

An evidence of this capacity, is the successful application of agents in different situations of Ambient Intelligence, like: culture, education, medicine and robotics [2]. Allied to this view, the evolution of mobile computing strengthens the possibility of acquiring information about the context and to respond physically in innovative ways [20].

The use of agents is therefore fundamental for a correct functioning of an Intelligent Ambient.

III. SELECTED RESEARCH PROJECTS

A. Evaluation procedures – criteria

The purpose of this work is to identify research opportunities in the field of Ambient Intelligence. To that end, a set of criteria were defined to evaluate the selected projects. Such criteria focused mainly on: situations, difficulties, technologies developed, mechanisms and devices that can be used. Some of these criteria were refined for a more comprehensive analysis of the projects and also to establish a relation between the project that we present in the AmI area and these projects. The criteria selected for reviewing the projects were:

- Devices: to identify the devices and mechanisms created or used in the development of the project;
- Objectives: to determine if the objectives defined were achieved;
- Key features: to facilitate the identification of the project and its context / area;
- Publications (P): to check if the project is recognized in the scientific community;
- Interactivity: identify what type of interactivity was created between the people and the ambient;
- Technology: to identify the basis technologies involved;
- Funded (F): indicates if the project was funded.

- **Methodology:** to analyze the methodology used in the project development;

The analysis of the projects by these set of parameters is expected to allow us to identify important issues and pitfalls when researching within this field.

B. *Projects' selection*

To begin this research in Ambient Intelligence nine projects were selected, from the several identified in this area. These nine projects contained more relevant information to make a thorough study based on the criteria previously defined to achieve a significant and conclusive result to start a research project in Ambient Intelligence area.

The following list contains a summary of each project in light of the criteria described previously.

1) *Life Spaces*

This project developed innovative systems sensitive to the ambient with the possibility of interactions between the virtual and the real world and are considered in several situations., through ambients that "come alive", which are associated sounds and custom images and people can walk through them. (at <http://www.ami-lab.org/>)

2) *AmI Vital*

The project *Digital and Personal Environment for Health and Welfare* proposed the development of a modern technological platform which will sustain the creation of applications and services in context of personal ambient, from a perception of social relation, health care and welfare significance to people with special needs. (at <http://www.amivital.es/>)

3) *LifeWear*

This project is intended to cover the current or future necessities of people, using electronic devices and interfaces. The researchers created devices and systems that can be used in the body and actions can be monitored in real time, allowing the understanding of the human actions in different conditions. (at <http://www.lifewear.es/>)

4) *mIO!*

The main research of this project was centered on study the ability of terminals to communicate with people through sophisticated interfaces based on immersive augmented reality. Another line of investigation was the creation of technologies that enable ubiquitous services and personalised to each person and his context using interactive mobile handsets responding to those services. (at <http://www.cenitmio.es/>)

5) *IRoom*

The project Intelligent Room was focused on an experimental platform for investigation on ambient computing systems. This room is prepared with sensors and effectors (light sensors, temperature, cameras, microphones, motion detectors, remote controlled electrical switches, speakers, screen, etc.) and includes real furniture (sofa, table, telephone, television, etc.). These sensors and effectors allows the gathering of information about people and their ambient, express valuable information for the people and produce

actions on their ambient appropriately. (at <http://iroom.limsi.fr/>)

6) *Amigo*

The research of Amigo project was aimed at implementing middleware that incorporates different systems to complete interoperability between services and devices. This interoperability between different domains can also be extended over different locations. (at <http://www.amigo-project.org>)

7) *THOFU*

This project consisted of an investigation of new tourism concepts and how these concepts guide technology research and development of technological concepts to enable an open offer of advanced services, different and exclusive around the hotel. (at <http://www.thofu.es>)

8) *Oxygen*

Project Oxygen enabled a pervasive and human-centered computing through a combination of specific human and system technologies. Speech and vision technologies aim to make the communication with Oxygen system as simple as interacting with another person, saving much time and effort. (at <http://www.oxygen.lcs.mit.edu/>)

9) *Ambient Agoras*

In this project the functionality of the computer was available in a ubiquitous and invisible mode, emerging two viewpoints: through the "physical disappearance", by reducing the size of the devices; and through "mental disappearance", by implanting the devices in the ambient. (at <http://www.ambient-agoras.smart-future.net/>)

C. *Projects' Publications*

Table I contains details regarding the publications that emerged from the projects under study, together with the associated events.

D. *Project comparison*

Table II presents the analysis of projects according to the criteria selected.

E. *Discussion*

All projects are directly related to the area of ambient intelligence, with two of them (number 2 and 3), also closely related to health and well-being.

Regarding the first criteria – Devices - it is concluded that most projects use sensors to obtain information of the ambient in which they are inserted and that mobile devices are commonly used in communication between the ambient and people. Projects 2 and 3 also use monitoring devices to collect data on persons. Some of the devices used in the projects are created by the researchers themselves in order to be adjusted to their needs.

In the second criteria - objectives - while all projects have a common objective - collecting information from persons and ambient - the main objective is different in all project, each one being directed to their focus of study.

In relation to the key features, these are different in every project, highlighting the idea of creating intelligent spaces where devices that surround people should gather information needed to analyze the development of the project and to obtain conclusive final results.

In publication criteria, it should be noted that from the 9 projects studied, 5 have indications of scientific publications and 6 are funded. Relating these two criteria, 4 funded projects have scientific publications.

Interactivity is one criterion present in a significant way in all projects, although it is stated in different ways.

Note that the augmented reality and virtual reality are listed on some projects as basis for interaction between the elements in the ambient.

The technologies used in projects are all developed by researchers in order to test the work developed, except in project number 7, because this project is divided into six sub-

projects with the objective of studying what are the best technologies to use in implementing a project in this area.

The methodology of each project is applied in accordance with necessities of each study in order to follow the better path of their research.

Some of the projects have the integration of different services through the interactions and social relationships. In these cases there is a concern for the welfare and people's necessities, trying to understand their behaviour.

The study of these nine projects using the evaluation criteria selected allowed to identify important issues to take into account in the development of AmI systems, such as interoperability between services and devices and type of devices more suitable for use in an ambient of interactivity. In the next section, these issues are faced in the perspective of future work.

TABLE I. PROJECTS – PUBLICATIONS

Project	Publications	Publication Theme	Participation in Conferences
P. 1 - Life Spaces	<ul style="list-style-type: none"> * Journal papers – 2011: 15 papers; 2010: 6 p.; 2009: 4 p.; 2008: 3 p. * Conference papers – 2011: 9 p.; 2010: 18 p.; 2007: 1 p. * Poster – 2010: 1; 2009: 1. * Book chapters – 2009: 4. 	<ul style="list-style-type: none"> * Multi-view Repetitive Structure Detection; * Understanding and Constructing Shared Spaces for Supporting Informal Interaction at A Distance; * Collective Sharing in Real and Virtual; * Activity recognition using dense long-duration trajectories; * Activity recognition using dense long-duration trajectories; * Novel interfaces for social and tangible interaction between remote persons. 	<ul style="list-style-type: none"> * 2011: ICTAI; ICCV; PIMRC; CAAD Futures; CVPR; ICC; CAADRIA; PerCom. * 2010: CHI; CAADRIA; ICCS; ICME; IEEE CVPR; UBICOMM; IEEE APSCC; SeNAI; SMC; ACM MoMM; ACM MM'10; ICDM; ECCV. * 2008: IEEE IC; AFGR; IEEE CVPR. * 2007: ISMAR.
P. 4 - mIO!	<ul style="list-style-type: none"> * Conference Paper – 19 papers. 	<ul style="list-style-type: none"> * Ambient Intelligence and Context Management; * Technology Access Interfaces; * Integrated Technology Environment for User Mobility; * Technology Services Environments; * New Technologies in Intelligent Infrastructure; * Connectivity and Communication Technologies. 	<ul style="list-style-type: none"> * Participation in 19 Events * 2010: X Semana de la Ciencia en Castilla; IX Jornadas de Ingenieria Telematica; XX Jornadas Telecom I+D; ICCGI; UCAmI; Interaccion; MobileHCI; ISAmI; EWSC; PPD10; IEEE Symposium on 3D User Interfaces. * 2009: Interacción 2009 Barcelona; Week @ESI 2009; EWSC 2009.
P. 5 - IRoom	<ul style="list-style-type: none"> Conference Paper – 4 (1 invited speaker). Poster – 1. 	<ul style="list-style-type: none"> * Multimodal Interaction within Ambient Environments; * Influence of System Output Modalities on User Input Modalities; * Ambient Multimodal Human Computer Interaction; * Intelligence Ambiante; 	<ul style="list-style-type: none"> * 2009: INTERACT 2009; European Future Technologies Conference FET09; Forum "Systèmes & Logiciels pour les NTIC dans le Transport" de l'INRETS; Journal of Ambient Intelligence and Smart Environments (JAISE). * 2008: 1st Digiteo Annual Forum.
P. 6 - Amigo	<ul style="list-style-type: none"> Conference Paper – 21 papers. Presentations – 3. Poster – 4. 	<ul style="list-style-type: none"> * Dynamic service composition in ambient intelligence environments: a multi-agent approach; * A multi-agent system for dynamic service composition in ambient intelligence environments; * Flexible composition of smart device services; * User requirements for Intelligent Home Environments; * Speech processing in the networked home environment. 	<ul style="list-style-type: none"> * 2007: TEI07; IUI07. * 2006: JCIW; AINA. * 2005: YR-SOC; PerCom; ICPCSC; Ubimob; SOC-EUSAI; INTERSPEECH.
P. 9 - Ambient Agoras	<ul style="list-style-type: none"> Conference Paper – 4 papers. 	<ul style="list-style-type: none"> * Situated Interaction with Ambient Information: Facilitating Awareness and Communication in Ubiquitous Work Environments; * Ambient Displays and Mobile Devices for the Creation of Social Architectural Spaces: Supporting informal communication and social awareness in organizations; * Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies. 	<ul style="list-style-type: none"> * 2004: CHI'04; * 2003: UBICOMP; Human-Centered Computing: Cognitive, Social, and Ergonomic Aspects; EUSAI; UEM; HCI International; SOC;

TABLE II. PROJECTS – CRITERIA

N	Devices	Objectives	Key Features	P	Interactivity	Technology	F	Methodology
1	Media devices.	Develop innovative sentient systems and environments; connection and social interaction between users in virtual world and people in physical space.	Virtual-real world interactions; context-aware systems and platform; pervasive communication infrastructure.	V	Virtual-real world interactions; connection and social interaction.	Technologies for network interconnection and integration; innovative systems sensitive.		Allow the community to participate with their contributions involving people in development of standards through an open platform.
2	Health devices; bio sensors; micro sensors; nano sensors; wearable sensors.	Development of technologies which will enable the easy creation of integrated services for health and welfare in the ambient intelligence context.	Device behaviour management; integral management of persons regardless the location.		Adaptive dynamic process of interaction because of the people profile diversity.	Localization systems, mobile system, home management system, fix monitoring system; Communications infrastructure.		Create a new paradigm in AmI spaces and develop a reference architecture and standard. Provide a technological platform and developing basic components of devices, networks and software.
3	Wearable devices; control-sensors; body devices; body-sensors;	Understand the different human bodies, so that actions and critical issues of safety and health can be monitored in real time.	Physiological monitoring.		Interaction with devices and electronic interfaces. HMI (Human Machine Int.) and HCI (Human Computer Int).	Integration of technology into the environment to human movement.	V	Creating systems and devices that can be used in the body and allows understanding the actions in daily activities of the person in different situations.
4	Display devices; multitouch interfaces; 3D interfaces; interactive mobile.	Interaction through mobile devices with services in intelligent ambient.	Immersive augmented reality.	V	Interaction with environmental services not only with the user, but also with other surrounding elements.	Technology access interfaces; technology integrated in environment for user mobility.	V	Improve and optimize their experiences during the project to adapt to technological change.
5	Sensors, actuators, effectors.	Get information from the environment and people to produce appropriate actions in that environment.	Ubiquitous computing; ubiquitous communication; intelligent user interfaces.	V	Touch screen and a remote control; System outputs could also use three ways: text, graphics, speech.	Several sensors and actuators linked through a dedicated network infrastructure.	V	Adaptation and interaction multimodal in heterogeneous persons and devices requiring a user friendly environment.
6	Mobile devices; physical sensors.	Provide services that enable sharing the activities and experiences in an easy and personalized form.	Open, standardized, interoperable middleware and attractive user services.	V	Usability and attractiveness of system.	Standard technologies providing to persons basic services.	V	Creating prototypes for design evaluation.
7	Monitoring sensors; virtual reality systems.	Investigate a new design hotel's future, since its construction, the spaces and objects placed in them, with particular attention to the guest interaction.	Customization of independent spaces; Intelligent and adaptive interfaces.		Augmented virtual reality in intelligent spaces;		V	Divided into subprojects each is related with a series of technologies.
8	Embedded devices; microphone; speaker; camera; accelerometer.	Create intelligent spaces inside offices, buildings, homes, and vehicles.	Multimodal perception.		Interaction with people through speech and vision.	Oxygen network and software technologies; perceptual/ user techn. (automation, collaboration knowledge access).		Using "Oxygen" technologies and systems on daily work.
9	mobile and embedded invisible devices; Personal "Artefacts": (ViewPort; Personal Aura; ConsulTable; InforMall; Hello. Wall; VideoMaton)	Devices become "invisible" reducing to the maximum the material or embed in the environment.	Invisible devices: "physical disappearance" and "mental disappearance".	V	Augmented reality.	Sensing technologies; smart artefacts (walls, table's mobile devices).	V	The ambient will be installed and valued in real work environment which will be used as a test.

IV. CONCLUSIONS AND FUTURE WORK

In Ambient Intelligence, context-sensitive technologies are used to recognize the stimuli of ambients and people. These intelligent technologies must manage all the information in order to provide the proper interaction between the ambient and people [10].

In this area, people can interact with the ambient and this should understand the human necessities and forecast the behaviour [21].

Although the researchers of the projects are concerned with the points mentioned above, they do not relate the different human tastes or explore combination of profiles, in the projects. The most practical experiences on Ambient Intelligence related to the collection of human profiles are still very incipient, possibly because the concept is recent.

Only the researchers of project number 2 were concerned with the interaction of people due to differences in user profiles and as a solution to this concern they proposed to create an adaptive dynamic process of interaction that will respond differently each time, according to the necessities of the person. But even this project does not stress the concern of creating a homogeneous profile of the people.

The projects surveyed are still highly centered in the physical ambient that surrounds the humans and not showing the characteristics or necessities of humans. These projects do not explore the potential of human profiles in the context of ambient adaptation.

In future work, the authors aim to implement an intelligent system located in an ambient for collection of certain features included in the humans profiles present in these ambients.

The scenario described is an ambient with smart functions and must be context-sensitive, because in these ambients the intelligent interfaces can understand and react to people [22], as evidenced in this paper, which means the sensors or integrated devices in the ambient have to transmit the states and significant actions of humans. These collected features will be later treated to adapt the ambient to the humans profiles. In other words, the main objective is to extract a single dominant human profile from the different human profiles collected and, with this dominant profile, to try to create an ambient more pleasant and adapted to the human's necessities.

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