Support ambient intelligence solutions for small to medium size enterprises: Typologies and taxonomies for developers

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Abstract

This paper examines the concept of ambient intelligence (AmI). Currently research in the area is ambiguous. There are not many definitions and consequently it is difficult to understand the concept. Definitions are fundamental to the understanding of AmI as they illustrate the properties of AmI. This paper seeks to address this deficit. It presents a research project called AMI-4-SME that aims to explore and develop systematic innovation in manufacturing small to medium size enterprises using AmI. Specifically it attempts to define the concept and philosophy of AmI from a systems point of view. The contributions of this paper are towards a generic definition of an AmI typology, focusing in particularly upon systems development. A typology can better facilitate an understanding and communication of the AmI concepts and philosophy. The AmI system typology and AmI taxonomy is developed and discussed The AmI system typology illustrates the tasks and the skills that an AmI system must have. The AmI taxonomy shows the evolution of the technology.

Keywords

Ambient intelligence, typology, taxonomy, classification, systems development

1 Introduction

The business world is changing at an accelerated pace. Product life cycles are becoming shorter, demand for newer more user-friendly products is increasing and the cost of manufacturing these products is being driven lower [Baker, 2002, Cox, 1997, Drucker, 1998]. One of the answers to these problems is to innovate [Atuahene-Gima, 2005, Horn, 2005, Tidd, Bessant and Pavitt, 2005]. Ambient Intelligence (AmI) can be used as a conduit to achieve innovation [Aarts, 2005,]. AmI is a people centred technology that is intuitive to the needs and requirements of the human actor. These non-intrusive systems are adaptive and responsive to the needs and wants of different individuals. The AMI-4-SME project plans to explore and develop systematic innovation in manufacturing small to medium size enterprises (SME) using AmI. The expected benefits for SMEs are that they will be able to cope better with a future where products and services will become human-centred, and users will have far greater involvement in the design and development process The project consortium is comprised of three main groups; research development partners, technology vendors and six SME organisations (Ireland, Germany, Spain and Poland). The project will develop two manufacturing scenarios, one for multi-stakeholder involvement in maintenance and another for assisting in dynamic reconfiguration of distributed assembly and manufacturing processes for shop floor control. AmI philosophy will be used in developing practical application for these two manufacturing scenarios.

SME's are important because they create employment, play a critical role in innovation and overall they are crucial to the economy because they fill the gap that large companies cannot or are not interested in filling. As a sector of the economy, they have grown and become more important over the last twenty years [Acs and Andretsch, 1990, Bellon and Whittington, 1996, Storey, 1995]. SME's make up the bulk of the enterprises in the Euro zone and in the United

Kingdom as a whole they make up "99.8% of business, 55% of employment and 51% of turnover" [Small Business Service, 2001]. Due to these factors and the development of AmI as a leading vision of the European Technology Research and Development program, it has become crucial to involve SME's in these forthcoming developments. SME's in their nature are dynamic, flexible and innovative, but are not always at the cutting edge of technology. The nature of their structure means that Information Communication Technology (ICT) systems that are designed for larger companies fail to meet their need and requirements. AmI by being human centric allows itself to be easily adopted by these companies.

Over the last decade, there has been a failure to realise the anticipated benefits of early ICT solutions. Research indicates that this was primarily due to poor implementation and little understanding and support by those in a senior management positions [Adeoti-Adekeye, 1997, Gardner and Ash, 2003, Wood and Caldas, 2001]. The new technologies that are being developed will focus on the human actor and will employ new universal innovation approaches in the area of AmI [Kirchhoff, 2005]. The services that the businesses will be able to offer their customers will allow them to secure their existing customer base and expand their market share.

The primary objective of this research is to provide a better understanding of AmI from a systems development viewpoint. Key challenges for the development of AmI are discussed and solutions are identified and presented. Existing definitions of AmI are discussed and a definition for AmI is developed. As AmI is in its infancy it is important to develop support structures that will not hinder its development. This can be accomplished through the development of typologies that assist in a common understanding of the philosophy. Typologies are groupings of models that can describe aspects of the same characteristics. This paper identifies some useful typologies that can be used to assist in the development of AmI systems. The typologies are part of an AmI systems development methodology that is being developed as one of the deliverables for the AMI-4-SME project. The contribution of this paper to concurrent enterprise lies in the area of design of products in a flexible organisation using AmI.

2 Understanding AmI

Ambient Intelligence is a new paradigm in the area of ICT, as such it is ill defined which is at present hindering its development. However, AmI has many potential benefits as highlighted in the ISTAG: Scenarios for Ambient Intelligence 2010 [Ducatel, Bogdanowicz, Scapolo, Leijten, and Burgelman, 2001] scenarios cover everything from the social, work and home environments in which AmI will exist. In the area of AmI manufacturing this involve products and services becoming human-centred, and users will have far greater involvement in the design and development process. Products will be intelligent and they will be able to interact with other technologies, but the human user will control the level of interaction. AmI is an evolution of the different categories of technology that have come before it, see figure 1.The x-axis represents the role of technology as an enabler and a transformer. The enabler technologies facilitate the advancement of technology at a technical level. The transformer technologies permit the advancement of the technology at a more human centric level. The y-axis represents the degree of change in the technology model as tactical and strategic. The tactical change represents the approach taken to overcome a specific problem. The strategic change is a part of a long-term plan that will achieve the overall goals. They have been built on each other and enhanced the technology further. This provides us with an appreciation of where it came from and what it is built on.

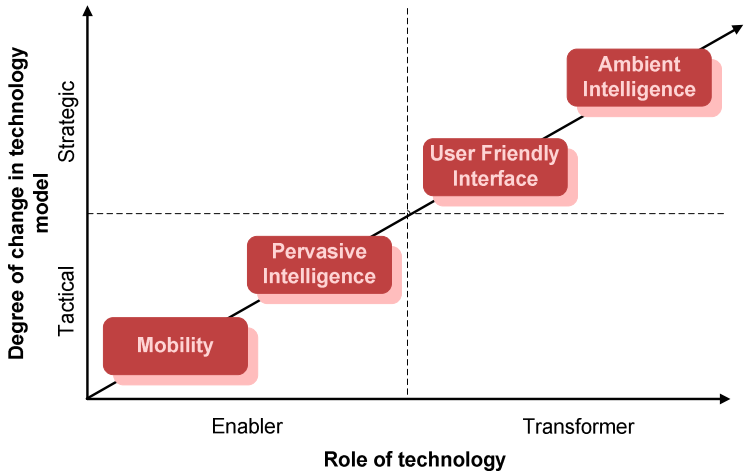

Figure 1: AmI Evolution

Definitions are fundamental to the understanding of AmI as they illustrate the properties of AmI and they explain the term in relation to related terms. They lay the foundation of our understanding of this new concepts. AmI is lauded to be "*an exciting new paradigm in information technology*", in which "*people are empowered through a digital environment that is aware of their presence and context and is sensitive, adaptive and responsive to their needs, habits, gestures and emotions*"[ITEA, 2003]. AmI is a pervasive and proactive technology that is omnipresent. Horvath [2002] develops the definition further in practical terms, *"this means we will be surrounded by intelligent interfaces embedded in everyday objects such as furniture, clothes, vehicles and roads."* He also highlights the fact that the technology will be omnipresent and learn "*these interfaces register our presence, automatically carry out certain tasks based on given criteria, and learn from our behaviour in order to anticipate our needs."* Lindwer et al [2003] delves more into the human actors interactions with the AmI system and defines it as a technology that is *"invisible, embedded in our natural surroundings, present whenever we need it,"* the technology is easily *"enabled by simple and effortless interactions,"* that are *"attuned to all our senses, adaptive to users and context and autonomously acting"*. For the purposes of this paper, the authors define AmI as a people centred technology that is intuitive to the needs and requirements of the human actor. They are non-intrusive systems that are adaptive and responsive to the needs and wants of different individuals.

However, the definitions of AmI are not that useful to those in the AmI design and development community. As Lindwer et al. [2003] highlights there is a *"large difference in abstraction level between the thinking about Ambient Intelligence systems and the micro-, nano-, and optoelectrical components needed to implement those systems"*. This evidence would suggest that definitions of AmI need something extra to assist them in the development of AmI systems. A generic typology for AmI systems is necessary. It is a crucial part of the AmI methodology for systems development that is being developed as part of the AMI-4-SME project. This typology should assist the developers, by having a better understanding of the AmI paradigm. It will allow for the development of better AmI systems. The typologies are not panaceas. They will only assist in the development of AmI systems. The typology will also help in defining what AmI is and what it is not.

3 Research Approach

A research approach developed by Cormican and O'Sullivan [2003] was followed. The research methodology used in this study is illustrated in Figure 2. It contains five distinct phases; foundation, induction, iteration, presentation and verification.

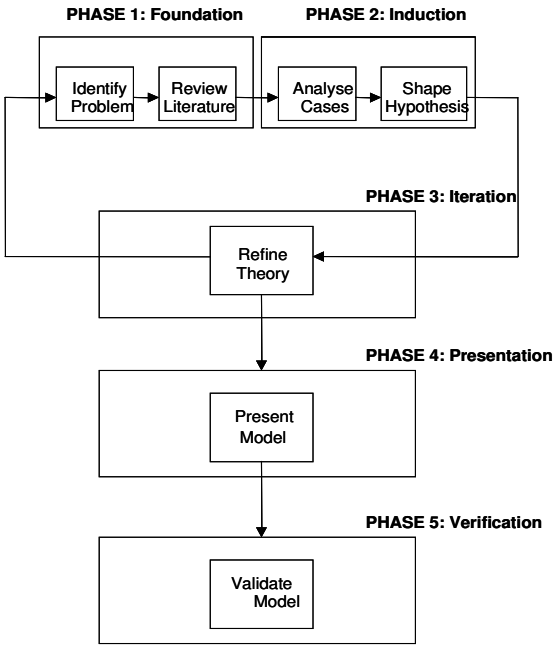

Figure 2: Research Methodology [Cormican and O'Sullivan, 2003]

- **Phase 1: Foundation** - During an initial review of the AmI technologies identified through the AMI-4-SME project along with business cases throughout Europe, an initial concept of what AmI is was discussed. It was found that there were differing opinions with the consortium on what constitutes AmI. From this meeting it was decided to develop typologies to assist in defining AmI in relation to the key six application scenarios. This was done to provide a more holistic approach to what AmI technologies are and the differences in applications. Following this, a review of literature relating to AmI was carried out. The scope of the review was literature in relation to AmI definitions, concepts, scenarios and applications. A summary of the findings of the review can be found in section 2. The objective of the models are to support AmI systems development. They are to be used as a tool for developers to better understand AmI and as such assist them in developing an AmI system.
- **Phase 2: Induction** - After an evaluation of the various definitions, concepts, scenarios and applications on AmI, a brainstorming session was held to further refine some of the initial ideas from the foundation phase. The brainstorming session was focused on AmI features, characteristics and technologies. Initial solutions were formulated in relation to the case studies. These involved using combinations of different technologies to develop the proposed AmI system for the different case studies.
- **Phase 3: Iteration** – Foundation and induction phases were repeated a number of times to refine and develop the initial typologies. The outcomes of the brainstorming session and following discussions were then used to develop the initial typology outlines. The ideas generated from the brainstorming session were analysed and refined until the components of the typologies that are illustrated in section 4 were developed.
- **Phase 4: Presentation** - The typologies are presented, explained and discussed in section 4. These initial typologies were presented to the SME case studies and have been used to provide a systematic approach to developing AmI systems.
- **Phase 5: Verification** –As is highlighted previously the typologies are being evaluated and verified within the framework of the AMI-4-SME project. This is being completed through empirical testing of the typologies during the design and development stages of the project. Further work-steps will involve validation of typologies throughout all six business cases.

4 Findings

A typology can better facilitate an understanding and communication of the AmI concepts and philosophy. A typology may also be known as a taxonomy or classification. The Oxford English Dictionary [2005] defines a typology as "*classification according to general type… the study and interpretation of types and symbols*". Typologies are therefore groupings of models, which describe different aspects of the same characteristics. In literature many models and theories can be found [Hellenschmidt and Kirste, 2004, Riva, Vatalaro, Davide and Alcaniz, 2005], these models and theories however do not take a combined view of the characteristic of what an AmI system should include. They look at the technological areas that AmI has evolved from and the technologies that can be used to initiate an AmI system. With regard to this the typology that is presented will help in outlining; what constitutes an AmI system, what are the unique characteristics and how it differs from other technologies and if not AmI what characteristics it must have to achieve AmI. The typologies below have been developed to assist in the understanding and the development of an AmI system. In particular to help to remove the ambiguity around what constitutes AmI. The first is an AmI system typology and the second is an AmI taxonomy. The AmI system typology illustrates the task and the skills that an AmI system must have. The AmI taxonomy shows the evolution of the technology in relation to three areas; mobility, pervasive intelligence and human and computer interactions in comparison to technology complexity and the development of higher value products for the end user.

4.1 AmI System Typology

AmI is centred on the human actors, because of this there are two main areas that together define what is and what is not an AmI system. The outer ring of Figure 3 represents the tasks that the AmI system needs to respond to and the inner ring has the skills that AmI system should contain. The tasks are person orientated, in that they represent the human characteristics that the AmI has to be aware of, in other words they represent the human characteristics that the system needs to recognise and needs to respond to. The skills are technology orientated, in that they represent AmI characteristics that the technology must have to interact with the human actors. They represent what the technology must innately accomplish as its aptitudes. Both are inseparable, interlinked and interdependent, the link between them is shown in Figure 3 below.

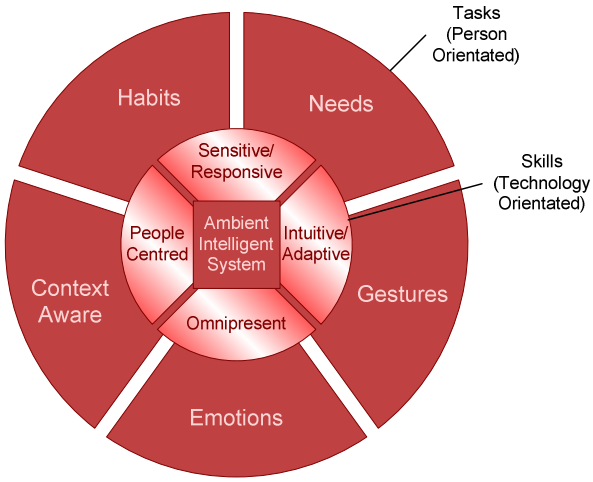

Figure 3: Ambient Intelligence System

The tasks are:

- **Habits** - A habit is something that we do often. The AmI system should recognise the users' habits and adapt to suit them. These habits may include the customs, routines, practices, traditions, conventions, patterns, tendencies, inclinations, likes and preferences of a person.

- **Needs** - A need is something that humans have to have to survive. The AmI system in a home may learn that one of the occupants is allergic to nuts and if food was brought into the home that contains nuts, it would inform the occupants. As such, it could recognise requirements, wants, necessities, the things we cannot do without, our must haves, essentials, wants and prerequisites.
- **Gestures** - This is the movement of body parts to convey feelings. AmI systems will be able to sense changes in humans from there body language and learn to adapt and respond to it. The gestures could be for example a motion, wave, shrug or a nod.
- **Emotions** - Emotions are feelings that one has. These feelings could be sadness, joy, boredom, etc. The AmI technology should be able to recognise the outward manifestations of the various emotions that humans experience.
- **Context aware** - The AmI is required to recognise the difference between, for example crying for joy and crying for sadness. The two would require a completely different response from an AmI system. This could be achieved through a combination of speech recognition software (SRS) and sensors that recognise differences in the human reactions, the AmI system should be able recognise the context in which the human actor is communicating.

The skills are:

- **Sensitive/Responsive** - The system needs to be tactful and sympathetic in relation to the feelings of the human actor, has to react quickly, strongly, or favourably to the various situations it encounters. In particular, it needs to respond and be sensitive to a suggestion or proposal. As such, it needs to be responsive, receptive, aware, perceptive, insightful, precise, delicate, and most importantly finely tuned to the requirements of the human actor and quick to respond.
- **Intuitive/Adaptive** - AmI needs to be able to adapt to the human actor directly and instinctively. This should be accomplished without being discovered or consciously perceived therefore it needs to be accomplished instinctively i.e. able to be adjusted for use in different conditions. The characteristics it is required to show are spontaneity, sensitivity, discerning, insightful and at times shrewd.
- **People centred** - AmIs most basic requirement is that it must be focused on the human actor. If a systems focal point is not the human actor then it is not an AmI system.
- **Omnipresent** - The AmI will have to be seemingly present all the time and everywhere. As such, it will have to be ubiquitous.

4.2 AmI Taxonomy

The AmI taxonomy (see Figure 4) shows the evolution of the technology in relation to three areas; mobility, pervasive intelligence and human and computer interactions in comparison to technology complexity and the development of higher value products for the end user. The taxonomy for example can be viewed in respect to the evolution of mobile communications. The x-axis represents the technologies complexity and the y-axis the higher value of the technology to the user. The technology complexity can be explained as the evolution of the technology; it becomes more complex as we continue to add on more options, requirements, applications, etc. The higher value of the technology refers to the user friendliness and improved usability of the technology or system, which increases the value of the product in the eyes of the end user. The elements of the taxonomy are as follows:

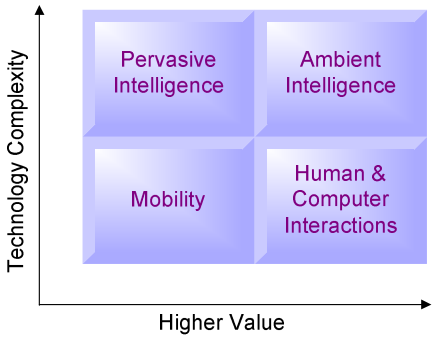

Figure 4: AmI Taxonomy

- **Mobility** - At a basic level, for example a pager that gives only mobility; there is no nice user interface.
- **Pervasive Intelligence** - Mobile phones for example that can interact seamlessly and invasively with technologies around them are an example of pervasive intelligence. This could be a mobile phone with Bluetooth technology that can interact with other mobile phones and with other technologies that have Bluetooth. The technology therefore begins to encompass and envelop the human actor and by doing so becomes omnipresent.
- **Human and Computer Interactions** - A mobile phone that has a user-friendly interface that allows one to track personnel goals and as such has all the functions of a Personal Digital Assistant (PDA). It can make connections and exchange data on your behalf.
- **Ambient Intelligence -** A combination of both the human and computer interactions that makes the technology user friendly and feel safe in the customers hands. The pervasive intelligence allows the technology to work unobtrusively in the background.

4.3 Implications and Next Steps

The typologies outlined above have been found to assist in defining AmI in the research that is being carried out in the AMI-4-SME project. They have been found useful in describing AmI to research colleagues and to refining the definitions of AmI, in so doing to making them more applicable for developers. The next step for the research is to validate the typologies during the specification of design and the implementation stages of the AMI-4-SME project. The typologies themselves are constantly evolving as new research becomes known, and these processes will continue as AmI evolves from its infancy.

5 Conclusions

The European economy is facing greater challenges from low cost economies than it has ever done before. Competition in the manufacturing sector is increasing fervently. As a result it is becoming more arduous for European SMEs to remain competitive. This can be achieved through innovation. AmI is a conduit to achieve innovation. The AMI-4-SME project plans to explore and develop systematic innovation in manufacturing SMEs through the use of AmI. AmI is people centred and intuitive to the needs and requirements of the human actor. They are non-intrusive systems that are adaptive and responsive to the needs and wants of different individuals. AmI will allow these companies to become more flexible and innovative. Current research in the area of AmI is ambiguous. Due to inadequate definitions it is difficult to understand the concept. As definitions are the foundation of our understanding of this new concept, a definition of AmI was developed and is presented with a set of typologies for AmI. The typologies are new models as they are based on the human side of the AmI, as previous models in literature concentrated on the technologies that enable the AmI system. The typologies outlined need to be empirically tested and will need to incorporate any new research in the area. These typologies will assist in the refinement of definitions and reduce the ambiguity surrounding AmI. The typologies also

help in the development of support structures that can be used by developers of AmI systems, as they will give a better understanding of the concept. The AmI definition and typologies that are presented are part of an AmI systems development methodology that is being developed in the AMI-4-SME project.

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