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# Understanding Ambient Intelligence: Typologies for Systems Development

## Abstract

This paper examines the concept of ambient intelligence (AmI). Currently research in this field is ambiguous. There are not many definitions and consequently it is difficult to understand the concept. 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 (SME) 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 particular 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 task 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]. 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.

Over the last decade, there has been a failure to realise the anticipated benefits of early communication technology (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 objective of this paper is to provide a better understanding of AmI and identify some useful typologies that can be used to assist in the development of AmI systems. A typology can better

facilitate an understanding and communication of the AmI concepts and philosophy. Key challenges for the development of AmI are discussed and solutions are identified and presented. 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.

## 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. They have been built on each other and enhanced the technology further. This provides us with an appreciation of where it came from, what it is built on.

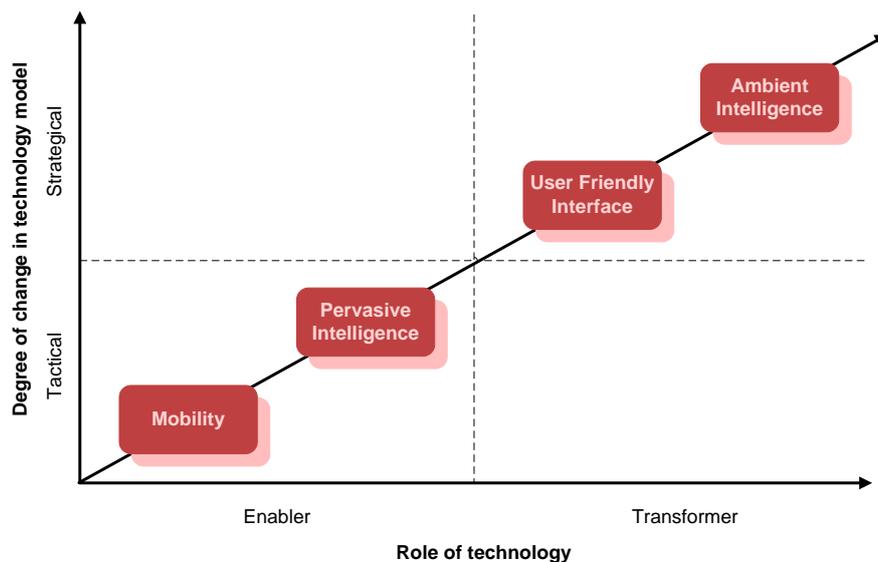


Figure 1: AmI Evolution

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*”. The definitions of AmI appear to be too conceptual to be used to assist in the development of AmI systems. For Europe to evolve into an AmI society this problem needs to be solved. A generic typology for AmI systems is necessary. This typology should assist the developers, by creating for them a measure to ensure that the technologies that they are developing are AmI. The typology will also help in defining what an AmI is and what it is not.

### 3 Research Approach

In developing the typologies, 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.

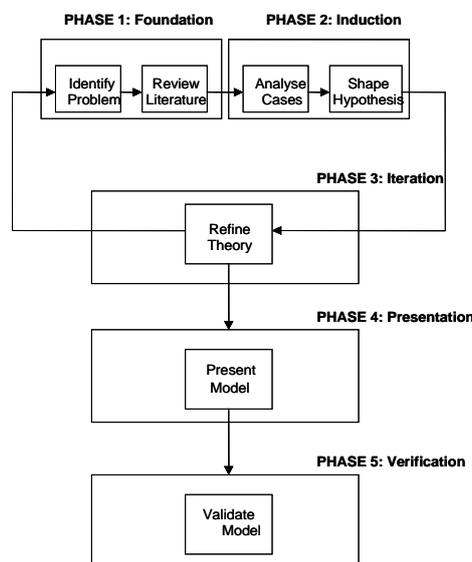


Figure 2: Research Methodology [Cormican and O’Sullivan, 2003]

The five distinct phases are discussed below:

#### Phase 1: Foundation

- Identification of Problems and Literature Review

As part of the preliminary work for the AMI-4-SME project, it was found that there are differing opinions within the consortium on what constitutes AmI. It was decided to develop typologies to assist in defining AmI in relation to the project. This was done to ensure a unified understanding of the AmI concepts and how it impacted the project. 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.

#### Phase 2: Induction

- Analyse of Cases and Shape Hypothesis

After an evaluation of the various definitions, concepts, scenarios and applications on AmI a brainstorming session was held to develop the ideas that were highlighted during the literature review. The brainstorming led on to discussions about specific areas that are obscure in the area to AmI. From this plausible solutions were developed in relation to the case studies.

These involved using combinations of different technologies to develop the proposed AmI system for the different case studies. The developments of the brainstorming session and following discussions were then used to develop the initial typology outlines.

#### Phase 3: Iteration

- Refine Theory

The typologies were developed and discussions were held with regard to them. From these developments, the typologies were further refined and developed.

#### Phase 4: Presentation

- Present Model

This is the current stage of the research. The typologies are presented, explained and discussed further.

#### Phase 5: Verification

- Validate model

The typologies are being evaluated and verified within the framework of the AMI-4-SME project. This is being completed through empirically testing of the typologies during the design and development stages of project.

## 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. With regard to this the typology will help in outlining; what constitutes an AmI technology, 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 human factors or functional requirements, and the inner ring has the AmI characteristics or technical requirements. The functional requirements are person orientated, in that they represent the human characteristics that the AmI has to be aware of, in other words they represent what the system must do. The technical requirements 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 do. Both are inseparable, interlinked and interdependent, the link between them is shown in Figure 3 below.

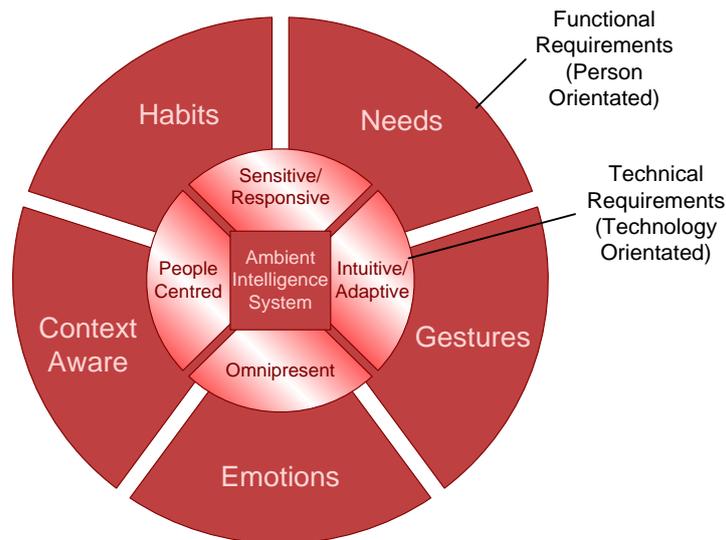


Figure 3: Ambient Intelligence System

The functional requirements:

- 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 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 their 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 to recognise the context in which the human actors are communicating.

The technical requirements 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 in need 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 technology evolves; 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:

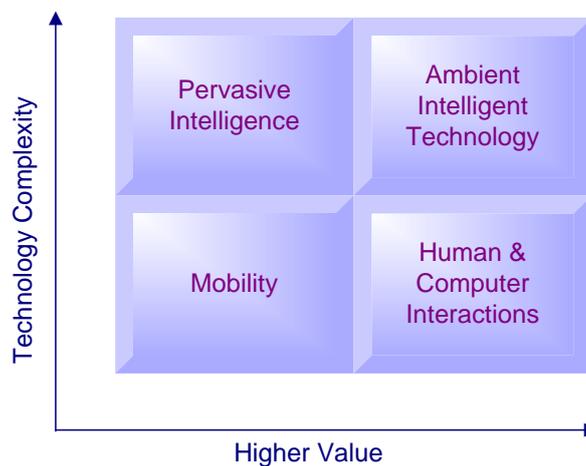


Figure 4: AmI Taxonomy

- 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. 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 be used in the areas of maintenance and shop floor control. AmI will allow these companies to become more flexible and innovative. Ambient Intelligence will not however take a foothold in the world unless it is properly defined and all the developers and researchers on the topic agree on a specific definition as to what constitutes an AmI system. The above sections have outlined a set of typologies for AmI, as used in the AMI-4-SME project. The typologies are new models as there were none previously and this opens a new area of research. 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.

### Acknowledgement

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