A methodology for modeling Ambient Intelligence applications using *i** framework

Alejandro Guzman[1], Alicia Martinez [1], Fabio Vargas Agudelo[2], Hugo Estrada[3], Joaquin Perez[1], Javier Ortiz[1]

[1] National Centre for Research and Technology Development, CENIDET, Cuernavaca, Morelos, Mexico {guzmanagc, amartinez,jperez,ortiz}@cenidet.edu.mx
[2] Technological of Antioquia, Medellin, Colombia.
fvargas@tdea.edu.co
[3] Industry Documentation and Information Fund, INFOTEC, Cd. De Mexico, Mexico
hugo.estrada@infotec.mx

Abstract. At present time, Ambient Intelligence (AmI) is a revolutionary computing paradigm that promises to have a deep effect on the way we interact with the computers, devices, physical spaces, and other people. The development of applications for this paradigm represents a new challenge for analysts and software engineers due to the complexity to consider physical, human and system actors interacting among them to give support to existing human activities. In this context, requirements engineering plays a very relevant role in AmI applications development because it allows the analysts to contextualize the expected functionalities of the system to-be before its implementation. In this paper, a technology modeling method, based on *i**, has been proposed as a tool to model the software requirements for Ambient Intelligence applications.

Keywords: Ambient Intelligence, software requirements, *i** framework.

1 Introduction

The vision of Ambient Intelligence (AmI) is to create a "physical world that is richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives and connected through a continuous network" [1]. The research works by Jaydip [2] stated that goal of systems of this kind is "to meet the claim of "everything, always, everywhere" for data processing and transmission through the ubiquity of ICT systems". In this sense, AmI systems can transform the way users interact with software and computers. Jaydip [2] established that "as computers are integrated into everyday objects, they will no longer be perceived as such and their usage will recede largely from our conscious perception". In this sense, AmI implies the development of new technological solutions. In the AmI approach, the systems must focus not only on computing devices, but also on objects and humans. In this sense, the devices will be able to take decisions and also, communicate with user and another devices [3].

However, the complexity of AmI systems, its complexity in the definition of the requirements for new types of interaction, intelligent systems, sensitivity to context and pervasiveness are fundamental concepts that must be captured. Therefore new tools are needed to facilitate the definition of requirements for AmI systems. This paper presents a methodology to face the modeling of AmI applications that considers the basic elements of an ambient intelligence applications using as basis the i* framework notation.

The paper is structured as follows: Section 2 describes the objectives of the research work. Section 3 presents the proposed approach for modeling software requirements for ambient intelligence applications. Section 4 provides the conclusions and future work.

2 Objectives of the research

The main objective of this research work is to propose a software requirements methodology for AmI applications that helps analysts to understand the role of the key actors of a system of this kind. To do this, two main objectives were identified: i) the development of a modeling methodology that extends i* models, and b) the development of a case study to provide an empirical validation of the proposed approach.

3 Scientific Contributions

The core of our contribution is the development of a modeling methodology that extends *i** models with elements specific for AmI systems. Three steps were followed to generate the proposed methodology: a) The analysis of existing methodologies for requirements engineering, b) the discovery of new modeling elements and c) the proposal of a requirements engineering methodology based on *i** framework.

3.1 Analyzing methodologies for modeling Ambient Intelligence applications

The methodologies selected are methodologies of requirements engineering. These are: (i) Documentation of requirements approached to users (DoRCU) [4], which is a methodology oriented to obtain software requirements (ii) Model requirements for embedded systems (ABS-Besoins-Sem) [5] a methodology of requirements adapted for building embedded systems applications. (iii) Requirements engineering for intelligence environments (RE4IE) [6], this is a framework for software system in intelligence environment. (iv)Approach for incorporating technology to business models [7], this research work presents a process for integrating business processes and technologies at the conceptual level.

The main objective of this analysis was to identify advantages and disadvantages of methodologies when they are used in a software requirements project of an AmI application. We also wanted to know if these methodologies could be adapted for

representing the key elements of AmI. In this analysis, some techniques and tools of requirements engineering like requirements classification, questionnaires, business and technology modeling, and basic notation of i* were analyzed. As result, we identified that they do not provide basic modeling concepts for AmI systems due to non-graphical way to represent the requirements, gaps in the representation of interaction forms and clarity in the specification. Therefore, the framework i* allow us to generate modules, model graphically and incorporate technology, which is useful for representing the elements of an ambient intelligence application. However, i* does not modeling a natural interaction among human and technology. For this reason we propose to extend this framework with a natural interaction, i.e. how humans interact naturally through his senses with the environment.

3.2 Discovering new elements of modeling

Ambient Intelligence is the vision that technology becomes invisible, embedded in our natural environment, present whenever necessary, accessible through systems of simple interaction, addressed to all our senses and adaptive to users and context [8]. Because of this, information and content should be available to any user anywhere. In consequence Irazabal [8], defines a set of elements such as: ubiquity, consciousness, intelligence and natural interaction as main characteristics of ambient intelligence. This idea is also supported by Vazquez and Lopez [9], that define the following attributes as key characteristics in environmental intelligence systems: 1) Computing, communication, and ubiquitous information, 2) Context sensitivity 3) Intelligence, and; 4) Natural interaction. In [10] the objective of AmI is enriching an environment with technology (mainly sensors and interconnected devices through a network) that can take decisions to benefit the users of that environment based on information gathered and historical data.

In this research work we unify the basic elements of an ambient intelligence application in: *ubiquity, intelligence, context sensitivity and natural interaction.* These concepts are modeled with proposed methodology.

3.3 Proposed methodology

The proposed methodology models basic elements of an AmI application: context, intelligence, ubiquity and natural interaction. The AmI applications need an implicit interaction with the users, unlike to the traditional systems that need continuous interventions of users for indicating to the system each action to perform. Our methodology is composed by four phases (Fig. 1): business modeling phase, technology modeling phase, interaction modeling phase, and finally, general modeling phase.

Business modeling phase. In this phase, the organization has been modeled through of an i* service model. The key idea of the service-oriented approach is to use business services as building blocks that encapsulate internal and social behaviors. In this model, we try to capture the *context sensitivity* through the business context [7].

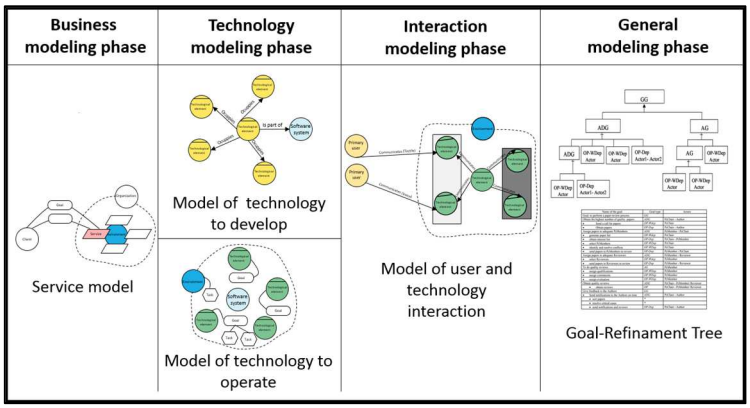

Fig. 1 Overview of our approach for modeling AmI applications

Technology modeling phase. This phase represents all technological components of the software system to-be. It is compose of two models: 1) Model of technology for development; 2) Model of Technology to operate.

*a) Model of technology for development***:** This model shows a representation of the technological elements required for application development. We use *i** Framework notation to represent the technological elements using *Agent* concept and the system that will be generated by using *Actor* concept. The objective of this model is to provide the analyst with the information about technologies involved in the application.

b) Model of technology to operate: This model shows a representation of the technological elements required for the operation of the application. We use a *protocol model* [7] for incorporating the technology. The objective of this model is to provide the analysts with the information about goals and functionalities of the technological elements into software system. This model describes the following elements of an AmI application: *Intelligence* defined by the main task and goals, and *context sensitivity* defined by the environments.

Interaction modeling phase. This phase shows the interactions in the software system between users and technology. We define three types of interactions: 1) human-technology interaction; 2) technology-technology interaction; 3) human-human interaction.

In this phase we propose the user-technology interaction model. This model shows the interactions that exist in an AmI application. The model incorporates the technological elements defined in the previous phases. The goal of this model is to provide the analyst with the information about the types of interactions that exist within the application. This model describes the following elements: *Ubiquity*, the technological elements that allows the system runs anywhere. *Natural interaction*, the specification of new ways to interact with the humans and technology.

General modeling phase. This phase provides information about organizational goals and the goals of the system to-be using a goal-refinement tree model. This model allows us to elicit the business goals and to represent these in a goal structure.

To do this, we use a goal classification, which permits us to construct a Goal-Refinement Tree (GRT) using refinement and abstraction strategies [11].

3.4 A case study

The validation of our approach was carried out in a real case study. This case study implements a software system for the detection of social isolation through AmI [12]. In this system software, the information is obtained in an automatic way using mobile phones and sensors (beacons)[1]. The goal of this case study was validate our approach and identify the requirements of a system AmI. In the service model, which is the first model developed in this case study, we identify the application context where the software system will be implemented.

The second model is the model of technology, which shows all technologic elements involved in the software system. Third model is the technology to operate, which capture the intelligence, and the context of each environment. Fourth model is the model of users and technology interactions, which capture the ubiquity and the natural interaction. Fifth model is goal refinement tree, which contains general information about the goals and objectives of the system software-to-be.

Due to space limitations, in this paper we only show the model of user and technology interaction (see Fig. 2) because we considered that this model visualizes more adequately the elements of an AmI system. In this model the actors are represent as users system, technological elements and the environment. The associations among users and technologic elements can be: *tactile*, *gesture and voice*. The associations, named communicates, show the interactions among the technological elements. The visibility between users and technologic elements are represented as white or black rectangle.

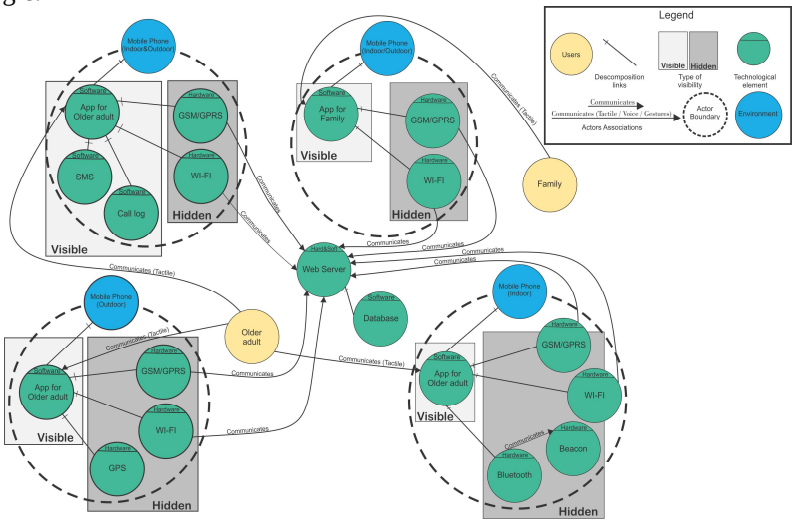

Fig. 2 Model of user and technology interaction

[1] Beacons. https://store.kontakt.io/our-products/27-bluetooth-beacon.html

4 Conclusions and future work

In this paper, a methodology for modeling software requirements of AmI applications is presented. This methodology consists of five models. In phase 1 we captured part of the context sensitivity with the business modeling. In phase 2 we captured part of the context sensitivity defining the environments in addition to capture the intelligence with the tasks and goals. In phase 3 we capture the ubiquity defining the technological elements of communication and also we capture the natural interaction with the actor associations indicating the type of interaction, the phase 5 show us overview of goals of the application. The results on the validation of our approach with the case study showed better clarity in the specification of the interaction between the user and the system. In addition to a concrete definition of the objectives and goals of the analysts. Currently, we are working on refining our proposed methodology for validating the identification of all elements of an AmI application. For to do this, we are working in several case studies reals of AmI applications.

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