Ontology for Simulation of Ambient Assisted Living Environments

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Abstract. This paper describes the ontologies developed in the framework of the European project VAALID. They are a set of OWL ontologies that are used to define Ambient Assisted Living (AAL) solutions, providing the semantics to model services, the actors involved in the service, AAL environments and their spaces, devices and furniture. The ontologies also include concepts to model the interaction among all the parts of the AAL solution, which mainly define requirements and restrictions. The model of interaction is based on the Common Access Profile.

1 Introduction

Ambient Assisted Living services (AAL), as other ambient intelligence solutions do, need to model the context in which the user is involved, being this one of their main goals. Among current definitions and references about context definition, Dey, Salber and Abowd give in [1] the following definition of what context is: "*Any information that can be used to characterize the situation of an entity, where an entity is a person, place, or object that is considered relevant to the interaction between a user and its application, including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects.*" Therefore, information managed by context is sometimes related to the environment, to the user and to the devices, plus a description of available services, in which both static and dynamic information is managed regarding all these concepts:

- User: concerning his/her profile (anthropologic, demographic, preferences), social relationships, activity (all types: sports, hobbies, etc.), etc.
- Environment: concerning its users, devices, software, localization (geographical or abstract, global or local), environmental conditions (lighting, humidity, noise, temperature, etc.), etc.
- Devices: regarding potential users, network connections, CPU, display features, type of device, whether it describes a specialized device like a sensor or not, the type and value of the signal measured, etc.
- Services: dealing with the description of their functionalities, the flow, the parameters, type of invocation, etc.

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This information allows defining flexible AAL services with a high level of detail (or the amount of detail needed) by describing both the potential users who will consume the applications and services offered and the localization, the activity of the users, their preferences, the time stamp, etc.

All the effort and time invested in describing the context hasn't been in vain, since it will allow increasing the personalization capabilities of the application and services. It will also allow increasing the automation of everyday activities by means of counting on accurate data retrieved from the environment, etc. As a result, the user satisfaction when making use of these services has been increased.

The ontologies described in this paper have been developed in the framework of the European project VAALID [17]. The VAALID project aims at creating an open and descriptive formal model to define "the users", "the environments" and their "interactions" of AAL services and solutions [18]. VAALID project intends to develop tools in order to assess that AAL products and services fulfill the accessibility and usability requirements and restrictions for this new combination of interaction modalities when used in a service design.

1.1 User

The information regarding the user must be more specific. In addition to define the profile and activities of the user, it must identify the skills, abilities, impairments and diseases (only with informative purpose), because all this information characterizes how the user will interact with the whole system. These concepts can be divided in psychological, social, and physiological/biological. Moreover, the description of how these characteristics change with the ageing process has also been added. The International Classification of Functioning, Disability and Health (ICF) [2] was chosen as the classification to be used.

ICF aims to be the standard language for the description of users. ICF is divided in different domains, which are described from the body, the individual and the society perspectives, distinguishing two parts:

- Part 1 is related to functioning and disability, and consists of 'body functions and structures' and 'activities and participation';
- Part 2 is related to contextual factors and consists of environmental factors and personal factors.

As ICF classification addresses a very broad range of concepts, we need to focus on a subset of concepts that are relevant for the design of AAL Solutions.

The selection of concepts from the ICF body of knowledge has been based on the "*Design for All*" guidelines for ICT products and services provided by the ETSI [3], in particular, the desired attributes of the users to be taken into account when designing ICT products that are:

- Sensory abilities such as seeing, hearing, touch, taste, smell and balance.
- Physical abilities such as speech, dexterity, manipulation, mobility, strength and endurance.
- Cognitive abilities such as intellect, memory, language and literacy.

1.2 Environment

Concerning environments, the most frequent environments in which AAL services are deployed are "*enclosed*" spaces as residences, hospitals or houses, although there are other services intended for being deployed in more "*open*" spaces like train stations, metro stations, etc. Here it seems clear that a distinction between indoor spaces and outdoor spaces will be needed:

- Outdoor spaces can be seen as those spaces that are typically represented in 2D defining a geographic space like a region or an area, even a building (in fact building can have 3D representation), which can be located by means of using an absolute reference system like the latitude-longitude-altitude or the Universal Transverse Mercator (UTM), or can be located by using relative references like landmarks or points of interest.
- Indoor spaces are those spaces which are more conceptual; they are typically represented in 3D and can use absolute or relative reference systems.

Several classifications about this matter are available being particularly interesting the one proposed by Hightower and Borriella; in [4] they propose a taxonomy of location systems for mobile-computing applications.

Together with the environment, we need to have the information about the devices contained in and that provide the functionality to the AAL Service.

In addition to all that, the most important goal for modelling the elements participating in an AAL service is to evaluate the interaction between them in terms of the accessibility facets, consequently a very important need to cover with the models is the information related to the interaction capabilities and its accessibility.

2 Review of Current Approaches

From the huge variety of approaches that can be consulted in the literature related to context modelling, we have reviewed the ones from the following list: Amigo EU project [5], Soprano EU project [6], DomoML project [7][8], DogOnt project [9], CODAMOS project [10], SOUPA ontology for pervasive computing [11], CONON ontology [12] and COMANTO ontology [13][14].

Most of these solutions provide OWL ontologies. Some of the ontologies reviewed explicitly say that they reuse other ontologies, for example Soupa or Amigo. The ontologies DomoML, DogOnt have some parts based on standards. Apart from defining concepts related with the requirements pointed out in the introduction chapter, some ontologies also provide concepts to define the quality of service (Amigo), or are oriented to domotic systems (DomoML and DogOnt).

Concerning how they manage the user information, the ontologies DomoML and DogOnt don't hold information related to users, perhaps because they could rely on reusing other existing ontologies for user modelling. The rest of them hold information about demographic data (Name, address, nationality, etc.). However, only some of them also maintain anthropological data, but this information is limited to hold Gender, Height and Weight. About concepts for defining skills, limitations and impairments, the ontologies here reviewed were not intended for modelling this area: Amigo provides concepts to hold information about skills and personality behaviour, but they are "upper" concepts; the same occurs with Codamos, it provides concepts to hold mood and role but not further information about skills or impairments. The Amigo ontology allows defining the user context for a lot of concepts, including personality and psychological features, or preferences about devices and foods. Soupa defines the class Agent that could be thought as an "alter ego" that acts in behalf of the user.

Information related to environment is present is some of the ontologies, the ontologies Amigo, DomoML and Codamos the environment can be located, but it doesn't have dimensions, only Soupa provides both location and dimensions. However, Soupa doesn't provide any environmental condition whereas Amigo, DogOnt, Codamos define environmental conditions like temperature, humidity, etc. The ontologies developed in Amigo, DomoML, DogOnt, and Soupa allow defining a lot of different types of environments. Moreover, Amigo, DomoML also allow to define a lot of types of object and devices and Codamos defines the classes Hardware and IODevice.

Services are described only in some of the approaches reviewed; Amigo and Codamos offer services by describing them as OWL-S. Amigo also provides the class Activity in order to define the activities of the user, whereas Codamos offers the classes Task and Activity. DomoML describes actions and services by defining sequences of operations, DomoML allows defining events and actions, but they are not part of the ontology. Finally Soupa doesn't provide real services, only classes Even and Action

3 Ontology Developed

After reviewing the projects and ontologies described in the chapter 2, none of them addressed the concept of the user in the way that was required , consequently a new ontology that were able to express the characteristics of the user in terms of abilities and capabilities to interact with other elements was needed. Other requirement is to define the properties that characterize the interaction between the elements and that could provide information about the degree of accessibility of this interaction. This approach resulted quite new and was not included in any of the reviewed ontologies, hence it was decided to create it new and adapted to these needs.

The ontology covers concepts related to model the context in which the user is involved, being this one of their main goals. Information regarding context is related to environment, users, devices, descriptions of the available services and the interaction among them.

According to the needs presented in chapter 1 and the results of the ontologies benchmarking presented in chapter 2, the following models have been defined:

- *User Model*: collect concepts related to profile (anthropologic, demographic), abilities, preferences etc. It is a new developed model as no previous work has been found to cover all requirements for this model.

- *Environment Model*: collect concepts related to elements present, devices, dimensions, environmental conditions (lighting, humidity, noise, temperature, etc.), etc.

Some device's taxonomies have been used from the ontologies reviewed in Chapter 2 and adapted to the needs of the project.

- *AAL Services*: collect concepts dealing with the description of their functionalities, the flow, the parameters, type of invocation, etc. It is also a new developed model, specifically tailored to requirements identified.

- *Interaction Model*: collect the concepts that describe the capabilities of each element present in the interaction and the accessibility aspects of this interaction. It is a new developed model that has been based on the new ISO/IEC 24756:2009 [15], which defines a framework for specifying a common access profile (CAP) of needs and capabilities of users, computing systems, and their environments, providing a basis for identifying and dealing with accessibility issues in a standardized manner across multiple platforms

3.1 User Model

This model is used to describe the relevant characteristics of the user or group of users that will interact with the AAL solution. These include physical and sensory attributes, habits, preferences and accessibility capabilities.

With this model the designer can define as many user interaction profiles as needed to address the whole range of requirements from target populations.

The user model is based on the ICF [2]. This standard offers a balance between a purely medical and a purely social approach of describing the limitations of people. This mixed approach allows grouping of limitations that are not only due to impairments but produce an equivalent result in the interaction with the proposed system

As the project focus on the evaluation of the interaction between the user and the AAL Service, out of the whole range of concepts that ICF offers to describe a person, the project has selected those having direct impact on successful use of ICT product and services, following the recommendations of the ETSI EG 202 116 [3]:

- *Sensory* abilities are *Seeing* (Visual Field, Visual Acuity and Quality of Vision), *Hearing* (Sound and Speech discrimination), *Balance* and *Touch* (Temperature, Vibration and Pressure).

- *Physical* abilities are *Endurance*, *Manipulation* (Lifting, Carrying or Putting down objects), *Speech* (Production of sounds and Production of Speech sounds), *Strength*, *Dexterity* (Pulling, Catching, Pushing, …) and *Mobility* (Voluntary and Involuntary Movements).

- *Cognitive* abilities are *Intellect functions*, *Attention* (Sustaining, Shifting or Sharing), *Orientation* (Time, Place and Person), *Language* (Reception and Expression of language) and *Memory* (Short and Long term).

The previous concepts where grouped in a higher concept call *Ability* as root of a taxonomy to define abilities, disabilities and impairments of the user.

As summary, an overview of the main concepts used in characterizing the user is depicted by the Figure 1. Users are defined by using the Person concept. A Person has a Gender, can be located in a Space, have a Contact Profile and a Profile. The Profile is used to define the Preferences, Abilities and Habits. Abilities have been described in the previous paragraphs. Concept Habit is used to describe the habits of the person, normally in relation to their needs for support in the AAL domain, i.e. cooking, eating, sleeping or taking medication. For these concepts is collected information about the usual time when are performed and for some concepts it is collected also the usual duration.

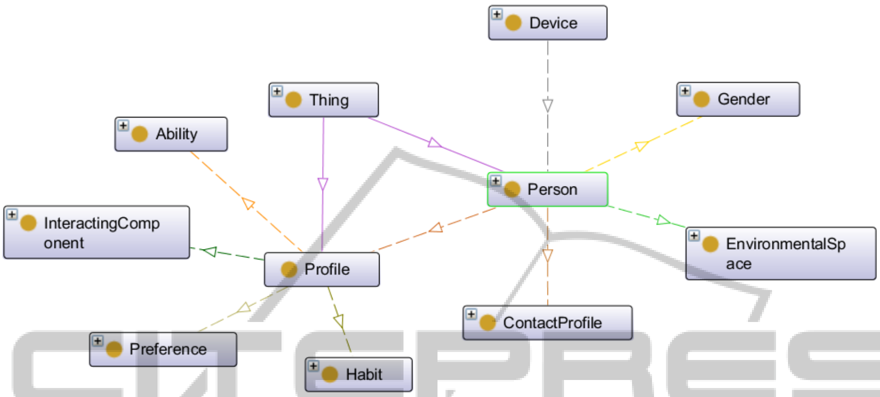

Fig. 1. Concepts and properties for person.

3.2 Environment Model

This model defines the concepts involved in the description of the pervasive technology within a real physical ambient. It includes description of physical spaces as well as sensors, actuators and any interaction device available to the beneficiary.

This model is particularly complex because in the case of environment and devices is needed to handle two types of behaviour, on one side the one that will be graphically represented in virtual reality during the simulation, for instance the movement of an opening door; and on the other side the one that will result in a interaction with the beneficiary, for instance a presence sensor that will send a message when activated.

The first one is done out of IDE developed within the project and it is part of a 3D scene file. The second one is done using workflows, defining the possible states of the object, the inputs that will change its state and the outputs it will provide to the system. The model has been defined in such a way to provide the links between these two behaviours in order to assure the consistency across the solution.

The Figure 2 shows the taxonomy and some object properties of the main concepts involved when defining an environment and the spaces attached to it. The *Environments* are defined as entities that can be placed at several *Floor levels*; each *Floor level* can be composed by several *Spaces*, each one of these *Spaces* can be categorized as *Rooms*, *Stairs* or *Ramps*. *Spaces* have *Dimensions*, have *Environmental Conditions* (temperature, humidity, …) and can be bounded by a *Polygon*. *Spaces* can contain several objects that are defined by the concept *EnvironmentalElement*, which define all kind of devices. *EnvironmentalElements* are categorized as *Controllable* or *Uncontrollable*. *Controllable* elements can define States, Services (functionality) and Communicate events. Some of the concepts covered by the taxonomy of *Controllable* are: *Appliances* (White and Brown goods), *Devices* (Sensors and Actuators), and

Lighting. *Uncontrollable* elements have been categorized as *Junctions* (Doors and Windows) and *Furniture* (Beds, Tables, Closets,…).

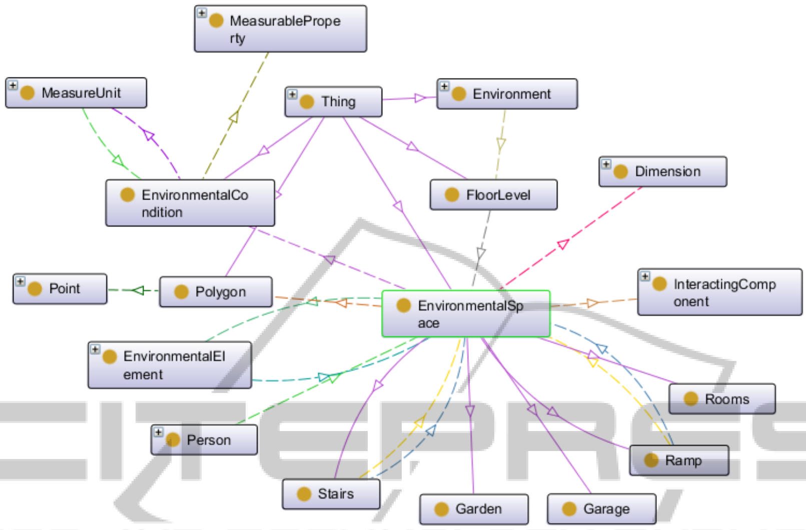

Fig. 2. Main concepts and object properties of the Environment model.

3.3 AAL Service Model

The AAL Service model is very simple, because it relies on the description of the dynamic between devices and user in the environment done by workflow, therefore only a set of properties mainly used for classification and general description of AAL services has been included in the model.

When defining an AAL Service it is provided the Context of use, a Description, the link to the Workflow that implements the behavior of the service, the Type of Service and the Actors involved.

3.4 Interaction Model

On the topic of defining interaction and accessibility, and in order to deal with the description of all the possible features of a user and the functionalities provided by devices and systems in terms of accessibility constraints, Fourney in [16] presented the Common Accessibility Profile (CAP); Fourney defines CAP "*as a framework for identifying the accessibility issues of individual users with particular systems configurations, defining and describing the needs and capabilities of systems, devices and users to communicate among them*". CAP has been taken as basis of the standard ISO/IEC 24756:2009 [15], although in this standard CAP is defined as Common Access Profile. CAP can be used to evaluate the accessibility of systems, services or solutions deployed in an environment for a specific user.

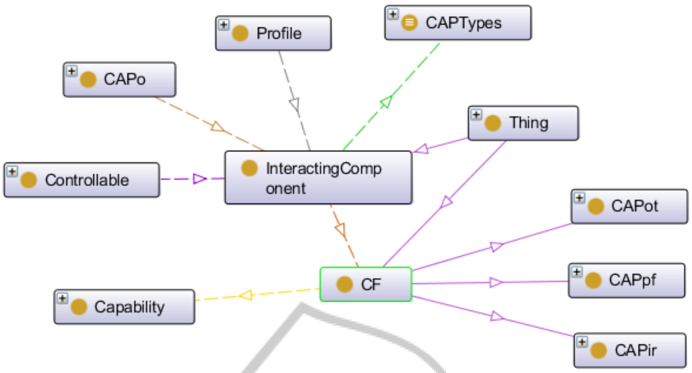

Fig. 3. Main concepts of the Interaction model.

In the context of an AAL project, this model is used in the Simulation Environment to perform the accessibility constraints verification; this functionality is used during the design and implementation phase and it allows the designer to automatically detect accessibility issues derived from matching accessibility profiles of the users with the different elements included in the simulation: environment and objects. It can be seen as the equivalent for AAL solutions of a tool for automated web accessibility evaluation.

The Figure 3 depicts the main concepts present in the Interaction Model: The CAP Overall of the AAL service to be modelled and used during the above-mentioned check is composed by the union of the CAP of the user (*CAPuse*), the CAP of the devices (*CAPsys* and *CAPat*) and the CAP of the environment (*CAPenv*).

By following this approach, the *CAPuse* is used to model the capabilities of interaction of a user; this *CAPuse* is aligned (partially automatically aligned) with the description done using the ICF descriptors. In the same way *CAPsys* and *CAPenv* describe the capabilities of the devices and the environment involved.

Each CAP is specified by means of its set of Interacting Components (*IC*), which can express a set of capabilities related to Input Receptor (*IR*), Output Transmitter (*OT*) or the Processing Functions (*PF*) that transform *IR* to *OT*. The definition of the *IC* and its properties permits to perform matching and checking of constraints automatically by creating an easy set of rules.

An easy example of how it works can be the following: a designer is developing an AAL service with an auditory alarm (fills the CAP of the system, the CAP of the devices, …), and selects a user with auditory problems (described with the ICF descriptors and his CAP); then, when the accessibility constraints verification is run, a warning will be thrown. In the same way the designer can test the solution with a vast variety of users (with different CAPs) and check how it adapts to the necessities of each user.

4 Conclusions

In this paper a set of OWL ontologies to model AAL solutions has been presented. It has also been presented the main concepts that compose them and also a review of the relevant solutions available on the field of describing AAL solutions.

In summary the ontologies described in this paper collect concepts to model the context, the environment, the devices, the user involved, the services deployed, and especially the concepts related to model interactions and allows the designer of AAL solutions to model and characterize the actors (the end beneficiary and other secondary actors, like relatives, formal caregivers, etc.) involved in the AAL service, define their abilities by using ICF descriptors. When defining an entire AAL solution using the VAALID ontologies, the restrictions set by the model can be checked by the VAALID Authoring Tool and the concepts collected by them can be also simulated by using the VAALID Simulation Environment.

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