On Context Modeling in Ambient Assisted Living

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Abstract. Within Ambient Assisted Living (AAL) context awareness is an important feature of intelligent user supporting services. In this domain different requirements regarding context modeling can be identified that are not in the focus of current context models. A consistent modeling approach is needed that supports different aspects of using context: dynamic integration of context sensors into a smart home environment, definition of service specific context models and end user interface for describing context dependent service behaviour. Current context modeling approaches do not fully meet these requirements. In this paper we introduce a three layer context model for AAL.

1 Introduction

The term ‚Ambient Assisted Living' (AAL) is used to describe technologies, which help to extend the time where elderly people can live in their home environment by increasing their autonomy and assisting them in carrying out activities of daily life. This technology is based on the installation of a smart home environment which integrates into the human living space and interacts with the inhabitant. Technologies that are relevant in the application domain AAL come from the research areas 'home automation' and 'ambient intelligence'

Research within Ambient Intelligence follows the goals of Ubiquitous Computing, which had been stated by Mark Weiser [1]. The computer should become invisible for the user. Instead the user should communicate with an intelligent environment naturally, which supports him in his goals. Natural interaction is achieved by providing interface support for language, movement, gesture and pointing [2]. Context awareness is also important to support natural interaction and to provide proactive services.

Based on these key technologies AAL services can be provided which integrate into the human's living space and provide intelligent assistance. Such services can be classified into the following categories: health, security, comfort, social environment and economy. Health services help to maintain the health of the inhabitant and to support medical care. One example is a personalized nutritional advice service [3] or the supervision of vital signs. Security services adapt the environment to the specific needs of the user. Comfort services can improve the living experience of the living space and also increase the autonomy of the inhabitant. These can be for example shopping and concierge services. Social services serve the maintenance and build up of social contacts of the inhabitant. Examples are video conferences or the usage of an awareness system [4]. Economy services help to save costs for the maintenance and operation of the dwelling. In [5] AAL services are additionally distinguished between indoor and outdoor assistance services. Current research on this level is focused on the identification, development and testing of AAL services. A number of test laboratories have been set up where AAL services can be installed and tested, e.g. HomeLab [6] or InHaus [7] of the Fraunhofer society.

Examples for AAL services can be found in [8]. We have developed and tested a number of AAL services in our project 'SmarterWohnen' [9][10] together with a local housing company in the city of Hattingen, Germany. A number of AAL services have been deployed in apartments, which have been equipped with OSGi based sensors and devices. These services are now used by a number of selected tenants. These include water and gas leakage detection, intrusion detection, house automation and health related services like the supervision of vital parameters.

In many of the AAL services context awareness is an important feature of the intelligent environment. We have implemented a context subsystem as part of the service platform, which has been used in a number of projects including 'SmarterWohnen' and a situation aware mobile tourist assistant for the Olympic Games 2008 in Beijing [11]. From our experience the development of context aware services for AAL puts special requirements on context modeling, which are out of focus of current approaches. Especially a consistent modeling approach is needed that supports different aspects of using context: dynamic integration of context sensors into a smart home environment, definition of service specific context models and end user interface for describing context dependent service behaviour. We propose a three layered context model as a solution to this challenge. Each of the layers is focused on a different aspect. In this paper we give an overview on our approach, which is part of the context subsystem.

The rest of the paper is organized as follows. In the following section we discuss the state of the art. After that we identify the special requirements on context modeling from the view of AAL. We then end with a short description of our three layered context model which we use for building AAL services and a conclusion.

2 State of the Art

According to Dey [12] context is "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves". A context model is a formal description of the relevant aspects of the real world. It is necessary to abstract from the technical details of context sensing and to connect the real world to the technical view of context adaptive applications [13]. There are already a number of approaches for context modeling introduced into the context awareness community. In [14] an overview on actual approaches is given. For example context models based on simple name-value-pairs have been used for annotation of services with context information [15]. XML-based context models have been used for providing context profiles, e.g. the comprehensive structured context profiles (CSCP) [16]. Currently ontology based context models are discussed in the research community, e.g. in [17].

In the AAL research community context awareness is also being discussed. In [18] some requirements for context models in AAL are identified: application adaptivity, resource awareness, mobile services, semantic service discovery, code generation and context-aware user interfaces. Based on these requirements an extensible context ontology is introduced that is focused on four main aspects: user, environment, platform and service. Based on that ontology services can be built that can adapt to changes along these four aspects. In [19] requirements are identified that are specific from user interface design for AAL services. Especially the acceptance of such user interfaces from elderly people is a key point in AAL. In [20] the focus is on enabling the user to define the context dependent behaviour of such services. A graphical programming language based on event-condition-action rules is introduced.

3 Requirements from AAL

There are already some approaches for context modeling in AAL as can be seen from the state of the art. Requirements have been identified and existing approaches have been adapted towards this domain. Nevertheless these approaches do not support a consistent modeling concept that considers all aspects from the integration of context sensors into a smart home environment, the definition of service specific context models and the provision of an end user interface for describing context dependent service behaviour. From our experience the following challenges concerning the model support of context aware applications within the AAL domain can be identified:

- The cost of setting up a context environment must be reasonable
- The cost for developing context aware applications must be reduced
- The diversity of available sensors within a smart home environment must be usable for context aware applications
- The set of context aware applications within a smart home environment has to be flexibly adaptable to the needs of the inhabitant
- The user has to be able to control the contextual aspects of the applications

An important aspect concerning the development of context-aware applications for actual use is the cost of the initial set-up of such context environments. Using existing approaches each context-aware application relies on its own specific context environment, which is not very cost-effective. The development of an architectural support for a multi-application context infrastructure is considered a solution to this problem [21]. Such an infrastructure allows sharing of one context environment between different context aware applications. It will allow the separation of concern regarding the provision of context information by appropriate context sensors and sources, and the usage of context information to make applications context aware. The openness and application independence of such a context infrastructure are still an open research issue.

The development of context aware applications is very expensive if it depends on concrete context sensors. There are a number of different context sensors from different vendors, e.g. location sensors, which have different interfaces and a different behavior. There is no common interface standard which could help to overcome the problem of sensor diversity. Again the provision of a multi-application context infrastructure can be a solution to that problem. The context infrastructure can provide a sensor abstraction layer, which hides away the diversity of available context sensors.

Different smart home environments may vary in their equipment with context sensors. Because of cost aspects and the increasing number of new sensor technologies there will be no fixed set of context sensors for smart homes. Each smart home environment will provide a different set of context information in different quality. Con-text adaptive applications cannot rely on fixed standards. Therefore they must be able to cope with that diversity appropriately. They must be able to evaluate the availability and usability of existing context information and possibly adapt their functionality e.g. by downgrading. A context infrastructure therefore must be able to provide information on available context information and its quality in a suitable manner.

Depending on the life and health situation of the inhabitant a different set of context aware applications might be of use for him. There will be no continuously fixed set of applications. A smart home environment must provide functionalities that support the integration of new context aware applications. A challenge here is to make a match between application requirements and context environment capabilities. An inhabitant, who is looking for suitable applications, needs feedback on the degree of context adaptability which the application can provide based on the environment and which extensions are needed in order to provide a full functionality.

When an application is integrated into the context environment the inhabitant might define the contextual aspects of the application's behavior. One such general aspect is to describe when the application should be activated in behalf of the inhabitant, e.g. activation of the comfort application only when user is inside his flat. Also some application functionality has to be customized by the inhabitant using context information. The inhabitant might from a privacy perspective also be interested in information about what kind of context information is used by the application in order to provide the desired adaptability. Therefore a context environment must provide a user interface to communicate context information to the inhabitant that hides away the complexity of context modeling and is easy to understand and handle.

3.1 Scenario

In order to demonstrate the identified requirements a scenario is given in the following. The scenario is about old Mr. Bond who is moving into a smart home. The initial set of context aware AAL services is not sufficient for his needs. Therefore he is extending his set of services using an open service marketplace. In order to use the full functionality of his smart services he is also extending the capability of the context environment by adding new context sensors. Then he is customizing the contextual behavior of the services according to his needs. This scenario is described in the following in detail.

Initial context environment and service set. The smart home of Mr. Bond is initially equipped with a standard set of context sensors: Time, in-house location, blood pressure, general in-house movement detection and state of different smart home facilities, e.g. heating, window, door, stove.

The initial set of context adaptive services for Mr. Bond includes a reminder service, a health service and an audio entertainment service. The services are available in Mr. Bond's Smart Living Manager (SLIM), which he can access using a mobile or stationary device, e.g. his television.

Fig 1: Available AAL services in the SLIM

Adding of new AAL services. Mr. Bond thinks that it would be great to extend his set of smart services with some functionality that could give him more control on the fancy smart devices in his department. He selects a house automation service from the AAL service marketplace and adds it to his application set. Immediately it is available in his SLIM. He starts to configure the new service. A number of smart devices are listed and also the actions that can be defined on them. Mr. Bond selects the lightings. He wants to have them turned on in the room where he is located, when it is dark and he is not sleeping. Mr. Bond gets informed that this service cannot be provided accurately, since there is no brightness sensor in his context environment. This context information is only provided by a simple context sensor, which derives the lightness from the daytime and season. Because of the missing sensor the functionality of detecting broken lights is not available.

Adding of new context sensors. Mr. Bond is satisfied with his set of assisting services. But he would like to extend their context adaptive features. He knows that additional context sensors are necessary in order improve the quality of service of the lighting control. Mr. Bond gets feedback from the application after activating the lighting functionality on the service that an additional brightness sensor can improve the quality of service. Mr. Bond engages a service provider to extend his context environment with the identified context sensors. The service provider integrates the new sensor hardware into the smart home network infrastructure. Then the context sensors are registered in the context environment.

AAL services with full functionality. After the new context sensors have been integrated in the context environment Mr. Bond starts to reconfigure his services. In the house automation service Mr. Bond recognizes that his selected lighting action entry is now provided more accurately and additionally with the broken light functionality. Mr. Bond is now satisfied with his services and enjoys the electronic assistance of his smart home.

Summarized, context adaptive applications in the AAL domain need an open multi-application context infrastructure which allows to handle the diversity and dynamic of context sensors and context adaptive applications and to provide user interfaces to communicate contextual aspects to the inhabitant. These challenges are not solved within the AAL domain - they are also still an open problem within the context research community in general.

4 AAL Three Layered Context Model

In the previous section we identified the basic requirements for modeling context in AAL. More requirements can be identified when we go into detail. In our approach we categorize these requirements into three different aspects of usage of context models: infrastructure, service adaptation and user interface.

On the infrastructure layer we identify the requirements that come from within the home automation infrastructure. This includes the network, computing knots and existing resources, e.g. sensors and actors. Also the ad hoc integration of context sensors into the context environment has to be supported.

On the service adaptation layer we identify the requirements towards a context model that comes from the context awareness of AAL services. The context dependent behavior has to be described on this layer. Also context dependent service selection has to be supported here.

On the user interface layer we identify the requirements that come from the interaction of a user with the ubiquitous environment including the AAL services.

The requirements on the three layers differ from each other. Consequently also context modeling and also the implementation of a context model on each of the three layers is different. However context modeling on the three layers is not independent. Changes on the infrastructure can have impact on the context dependent behavior and capabilities of the AAL services. The type of the AAL service has an impact on the context model on service adaptation layer, which also is reflected on the user interface layer. These three layers also represent a different abstraction from technical description of context to a user oriented representation.

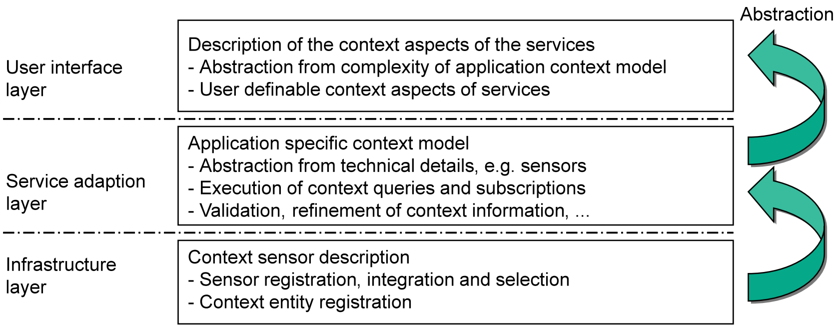

Fig 2: Three layered context model

In the following subsections a more into detail description of the three layers and the interdependencies is given.

4.1 Infrastructure Layer

The availability of resources on the infrastructure layer can change dynamically. The characteristics of the network and the reachability of computing nodes can be highly dynamic within a ubiquitous environment. In [22] the characteristics of three network types in Ambient Intelligence are analyzed: cable based and wireless networks, but also sensor nets. Computing nodes and their characteristics are examined in [23]. Nodes on the network are grouped into four types: fixed nodes group, portable nodes group, sensor / actuator nodes group and device group. Fixed and portable nodes are potential runtime environment for infrastructure services and applications. These services can move from node to node. The nodes have to provide the appropriate means, e.g. computing power and platform [18]. A context service is a specialized service on a fixed or portable node that provides context information using a sensor node. The availability of these resources on the infrastructure layer can influence the quality of service provided by the AAL services. For example the selection of the appropriate output device depends on it. Also the quality of context adaptivity depends on available context services and their quality.

The context model on this layer represents the existing infrastructure resources. We need to describe the resource types and their properties. The model then is used for the management of the infrastructure. This includes the ad hoc integration of resources by registration into the infrastructure. The context model has to support the retrieval of resources with given properties and quality features.

In a ubiquitous environment we need a representation of the existing infrastructure, e.g. networking, computing knots and other resources. Context services are additionally described with information about the context information they provide [21]: the type of entity or relation, the property of that type, quality of service and usage policies, e.g. business rules or privacy aspects.

For the representation of context information on the infrastructure level we use a metadata ontology, which is an extension to [18]. An infrastructure registry service has been implemented, which supports this ontology. The service provides methods for the registration and retrieval of infrastructure resources. This service has been integrated into our context subsystem. It can use these methods for discovery of appropriate context services.

4.2 Service Adaption Layer

The context model on this layer describes the contextual aspects that are relevant for the adaptivity of an AAL service. It abstracts from the technical details of context ser-vices within the infrastructure. Most context models identified and evaluated in [14] are on the service adaptation layer, e.g. [24-29]. The different categories of AAL services have different requirements and a different scope on context information that is needed. This leads to the demand for the definition of service or type specific context models. A context model for health services is different from that for security services. It focuses on vital parameters of the user and the definition of health related situations that can be derived. A service specific context model can be defined based on a context meta model. This meta model defines the concepts that are also common in state of the art approaches, e.g. context entities, relations, dimensions and attributes. A more in detail description of the meta model can be found in [21].

The definition of situations or high-level context information is an extension to the basic context meta model. All possible states of the service specific context model describe the valid context space. A context subspace is defined by extracting the relevant context entities and relations of the context space and by setting limitations on their context dimensions. These subspaces are then named and represent a corresponding situation.

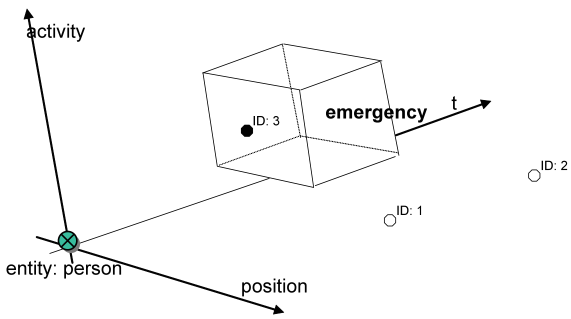

Fig 3: Context Subspace

The context model on this layer can be represented through an ontology. From our experience in practice we learned that existing ontology engines are not suitable regarding their non-functional behaviour, e.g. performance and scalability. This is due to frequent and heavy changes of context information represented by facts in the ontology. In [13] such limitations have also been identified. Therefore a combined approach of contextual ontologies and context models has been proposed in that paper. In our approach we extend the relational entity model with concepts from ontologies, e.g. standard relationships like subtype, instanceOf, partOf, geoContains [30]. This implementation is part of our context subsystem. It supports service specific context models based on the meta model. Methods for synchronous queries on the context model are provided. Also subscriptions on context information and named situations can be defined. Changes in context information which are described by the subscriptions are reported by throwing events. AAL services can use these methods to define the relevant contextual aspects in order to adapt their behaviour.

4.3 User Interface Layer

In a ubiquitous environment where the behavior of services does not depend on explicit user interaction it can be necessary to give feedback on the system's assumptions that lead to desired or undesired actions. The environment has to provide means for the user to control and to make corrections to the assumptions about the relevant context. Therefore these assumptions have to be presented in a way that is easy to understand. The context model that is used on this layer has to further abstract from the complexity of a service specific context. The same requirement can be identified for the configuration of AAL services. The user has to be able to define the context specific behaviour of his services. Here also a context model has to be provided that is targeted for user interaction. The context model in [20] allows a boolean conjunction of low level context conditions using a graphical interface and the definition of appropriate actions. This approach assumes technical competences that not all elderly people can and are willing to raise. Our context model on this layer allows the predefinition of situation taxonomies, which can be predefined for the different AAL service categories. The elements of the taxonomy may have graphical representations. These graphical representations can be used to visualize the relevant system's assumptions. Based on the taxonomy the user can also navigate and select a predefined situation in order to configure an AAL service. This situation description can further be refined based on the interdependencies to the service layer context model using a graphical interface.

4.4 Mappings

The context models on the three layers have a different focus and therefore differ from each other. Nevertheless there are dependencies between these models. Context information that is available in the infrastructure has to be mapped into the service specific context models. The common meta model elements of both levels are context entities, relations, dimensions and attributes. Based on these elements mapping between the two context models is supported using the following functions:

- selection: context entities, context relations and their attributes from the infrastructure layer can be selected and defined within the service adaption layer. These can be renamed.
- restriction: conditions for concrete context instances can be defined that should be part of the service specific context model. For example only instances of the entity

'person' with a value of an attribute 'age' above '65' should be part of the context model for services of the type 'health'.

- specialization: new context entities and relations can be defined on the service adaption level which correspond to existing entities or relations with defined at-tribute values. For example an entity 'person' with the value of an attribute 'age' less then 18 can be defined as 'child'.
- derivation: new attributes for existing context entities can be defined, whose values can be derived from other attributes. For example an attribute 'daytime' can be derived from the attribute 'time'.

The context model on the service adaption layer can define quality of service requirements that have to be mapped on available context services in the infrastructure. If the requirements cannot be met then the service specific context model cannot be fully supported by the infrastructure.

Situation definitions on the user interface layer have to be mapped onto the context model at the service adaption layer. At least the leaf elements of the situation taxonomy correspond to the named context subspaces of the service specific context model. Meta information on the context subspace about the included context entities, relations and attributes can then be used for further refinement on user level. If for example the time dimension is part of the situation definition, then a concrete time point can be further specified by the user. If a situation definition cannot fully be supported by the service specific context model then it should be disabled on the user interface layer.

These mappings and dependencies between all the three layers which have to be considered allow for an ad hoc integration of context sensors which can be automatically transferred into a service specific context model. These mappings also support end user context visualization and definition.

5 Conclusion and Outlook

We have described the requirements towards context modeling from the view of AAL. These requirements result from the highly dynamic infrastructure, including available context sensors. Other requirements can be derived from the need for changing AAL service sets which are adequate for the different living circumstances of a user. Also adequate user interaction concerning context information has to be regarded. We have introduced a three layered context model which support these different requirements. Already existing context models can be related to the different levels. We have shown the interdependencies between these layers. Using this three layered context model the development of AAL services can be supported. We have implemented and tested such AAL services using a context infrastructure, which supports this three layer context model. Following papers will give a more in-depth description on the different layers and technical aspects of our context model.

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