Representation of Integration Profiles Using an Ontology

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Abstract The Integration and commissioning of AAL systems are time consuming and complicated. The lack of interoperability of available components for Ambient Assisted Living has to be considered as an obstacle for innovative SMEs. In order to ease integration and commissioning of systems knowledge based methods should be taken into account to enable innovative characteristics of AAL systems such as design automation, self-configuration and self-management. Hence, semantic technologies are suitable instruments which offer the capability for mastering the problems of interoperability of heterogeneous and distributed systems. As an important prerequisite for the emergence of knowledge-based assistance functions a standard for unambiguous representation of AAL-relevant knowledge has to be developed. In this paper, the development of an AAL-ontology is proposed as a formal basis for knowledge-based system functions. A prototype of an AAL specific ontology engineering process is presented through the modeling example of a formal representation of a sensor block which is part of an AAL-Integration Profile proposed by the RAALI consortium.

1 Interoperability in the Context of Ambient Assisted Living

In order to enable senior citizens to grow old gracefully in independence from other people and institutions, it is mandatory to reconstruct their familiar environment in respect to their specific restrictions and demands. Technical solutions

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and services adopting the domain of AAL take the key position for the success to overcome the effects and implications of the demographic change. Due to their often overwhelming system architectures and their similarity to ambient intelligence solutions in general, the integration, installation and putting into operation of AAL-assistance systems is complex and elaborate. Due to the fact that most of the specific AAL-components are currently still remaining in the development process, standardized elements, parts and multi-sensor/multi-actuator networks from the building automation, telemedicine and ICT are applied for the orchestration of the hardware substructure of human centered assistance systems. Thereby, experts for the system deployment and installers are faced with still open interoperability issues. Manufacturers of AAL-system have either to rely on proprietary solutions or to care about a large number of partial disjoint standards and norms.

Nowadays, the obvious lack of interoperability regarding AAL-systems and components is commonly stated as one significant obstacle for innovation and development, especially for SME's. One promising approach to find a sufficient solution regarding interoperability criteria is granted by methods and techniques from the semantic web. Semantic technologies offer a couple of ideas and strategies to handle large, complex, heterogeneous and decentralized systems. Thereby, only the introduction of methods of knowledge processing is appropriate for the attainment of worthwhile targets as design automation, self-configuration of autonomous, distributed systems and the fully automatic self-management of AAL-systems. But initially, a machine-recognizable, formal representation for the unambiguous description of system-related knowledge has to be created. After that, necessary processes of deployment, launching and management of AAL-systems can be supported by knowledge based services. This chapter proposes the development of an AAL-ontology as a formal representation for knowledge-based system components. As an example, the preferred ontology engineering process is outlined through the modeling of a function block covering a RAALI-integration profile for sensor components. Hereafter, the prototypal executed ontology engineering process is the springboard for the integration of domain experts within the standardization process of AAL-ontologies.

Paper structure: In Sects. 1.1–1.3, the reasons for the use of ontology-based approaches for the representation of AAL-integration profiles including general the development effective properties of AAL-systems are explained. Section 2 deals with the state of the art regarding standards and norms and in addition, methods and techniques for the system design from the domain of telemedicine and building automation. Thereby, semantic based technologies which are suitable for the representation of integration profiles are objects of special attention. In Sect. 3.1, the first results from the funded BMBF-project *Roadmap AAL-Interoperabilitaet—RAALI*, the integration profiles, are part of the discussion. The ontology engineering process itself is subject of Sect. 3.2. This includes an expanded modeling example of a sensor node by the function block based approach and the aid of descriptive methods, depicting the current state of research.

1.1 Relevant Properties of AAL-Systems

Current AAL-systems have distinct specific attributes in comparison to classic technology developments. This fact regards the development process of components as well as the stepwise integration of such systems. Therefore, following aspects have to be considered:

(a) AAL-systems do not have a product life cycle in the terms of classical systems. In respect to the paradigm of an aging environment/home, it is necessary that the components are selected due to the altering needs of their residents. This implies that the assistance is mutable. From this point of view, the interplay of system components whose market entries are temporally wide apart from each other is an important property of aging environments. Furthermore, the different stages of an AAL-product as development, launching and the usual runtime can be associated by cyclic interacting processes which need to be synchronized.

(b) Common AAL-infrastructures are heterogeneous and characterized by the orchestration and integration of unusual components which typically do not belong to the domain of AAL. A complete setup of services and components from one single manufacturer or company is currently not available. Therefore, actual AAL-approaches subsume many devices of different distributors which lead directly to a significant workload for system integrators. These experts must handle about components from the telemedicine, building automation, ICT and probably, proprietary sensor solutions like UWB-sensors for vital sign acquisition.

(c) Mainly, AAL-systems depend on the integration of existing components. AAL-system deployment is therefore characterized by the use of descriptive, integration oriented methods because usually the system designer isn’t an expert in the specific domain of the target component. (e.g. not an expert for building automation) and hasn’t got any knowledge about the implementation.

1.2 Application Based Integration Profiles

One promising approach for the realization of interoperable systems is the definition of application based integration profiles. In the last ten years, these profiles have been approved in the area of medical IT. As a reference, the surveillance of vital signs in home care domains utilizing integration profiles from the *Integrating the Healthcare Enterprise-Initiative* (IHE) and the *Continua Health Alliance* (CHA) is a vivid example of practice [1–3]. These profiles describe the components including their interfaces by the aid of common standards in order to achieve the required Plug’nPlay functionality. The project *RAALI* adopts the principles behind these profiles to the domain of AAL. In addition, the development of a library of function block, covering manifold devices and software services of AAL, is part of the work in order to simplify the outline of complex AAL-systems.

1.3 Knowledge Management as a Way to Solve Interoperability Issues

In order to overcome current innovation obstacles, it is promising to pursue three main objectives:

- Simplification of the AAL-system deployment process through design automation.
- The initial start-up by the aid of self-configuration approaches.
- Maintenance of running AAL-systems by techniques of self management.

In accordance to current interoperability issues, the semantic technologies take a decisive role because the included knowledge bases services are appropriate to solve problems evoked by system runtime, heterogeneous structures and the diversity of system components. The interaction of the different stages in the AAL-product lifecycle as deployment, integration, initial start-up, maintenance and operation is the main reason for lifelong knowledge management. The introduction of knowledge based systems for design automation and the reuse of gained knowledge about the engineering process is crucial for the consecutive procedures of self-management and self-configuration.

1.4 Ontology Based Approaches for Life-Long Knowledge Management

The essential part of every knowledge based system is an ontology. Ontologies are known as a promising concept to describe a thing (resp. AAL-integration profile) or an object in a universal manner so everybody including machines gets a better understanding about the feature of interest and its properties. Logic based languages as *OWL 2*, established reasoning infrastructures for the implementation of inference processes and in addition, a couple of valid tools are a solid basis to start from. The introduction of an AAL-ontology, however, requires special considerations; the complexity of single AAL-components and complete AAL-systems is a challenge for ontology design. Each available technical component can be an element of an AAL-system if this system is designed for the specific functions of the high level application context. The apparent dynamic of AAL-systems prevents the design and finalization of AAL-ontologies. In addition, the large number of existing and pronounced products complicates the definition of a universal system of concepts. On the other hand, it is essential to evaluate and maintenance. AAL-ontologies continuously if they are determined to take the key role within a knowledge management infrastructure for the warranty of stable system functions during the development process or during runtime. To fulfill these demands in a sufficient manner, it is essential to integrate manufacturers, designer, system architects and installers within an unending standardization process.

2 State of the Art

2.1 Description Methods

2.1.1 Description Methods for Medical IT-Solutions

As mentioned in Sect. 1.2, the definition of use case based integration profiles for the realization of interoperable systems has been approved in the area of medical IT. These complementary integration profiles belong to a higher level of abstraction compared to established communications standards. Well known application scenarios from the health care system are the integration profiles from the initiatives *Integrating the Healthcare Enterprise* (IHE) and the *Continua Health Alliance*. In order to achieve a maximum of interoperability by the systematically use of standards, the IHE was founded by user and companies in 1998. For this purpose, the typical work flows in health care institutions were modeled and adopted to integration profiles which cover the transactions between the involved IT-systems in accordance to internationally accepted standards of biomedical technics.

2.1.2 Description Methods for Building Automation

Typical aspects of building automation components and topologies are described by the standard *IEC 61499* [4]. This standard comprehends the definition of a system itself, device, application and function block. The automation system can be described via a network of distributed sensor-/actuator components which are dedicated to a distinct process. The representation regards hierarchical aspects which is essential for the decomposition of the system due to a arbitrary number of levels. The aspect of decomposition can be applied for processes and components as well as for function blocks which encapsulate applications on a lower level (e.g. driver). Based on the input–output orientation, it is easy to combine and link different objects. The processing is executed within the basis-function blocks; the execution control charts of these elements are connected. Thereby, a automaton based approach including event chains resp. state sequences can be implemented. The *IEC 61499* standard provides a textual representation as well as a non-standard graphical representation for the system design itself. In the field of building control the *VDI guidelines 3813–3814* regulate with 48 different function block types for sensors, actuators, HCI, etc. algorithms the system design. The *VDI guideline 3813* enables the description of so-called automation schemes, which can be used as a rough draft in the planning phase. This means that system designers can focus on the functional relationships of the design and must not care about the detailed implementation knowledge. Thus, the *VDI 3813* grants a technology-independent specification of systems and their interaction.

2.1.3 Description Methods for ICT-Systems

A basic task in the modeling of information processing systems is the mapping of distributed processes and their communication. There are manifold possibilities for the modeling of often transforming, embedded technologies and systems. Basically, one can distinguish between constructive and declarative/descriptive methods.In the ICT sector, constructive methods are preferred. Constructive methods provide language elements which are important for the deployment of a first abstract system model. In the following step, the model can be defined, configured and implemented by semi-automatic or fully-automatic procedures. In the area of ICT one well known language is *Specification and Description Language* (SDL). SDL [5] leads directly to the development of a system structure which is called hierarchical decomposition (refer to Fig. 1) whose integral parts finite consist of *CEFSMs* (Communicating Extended Finite State Machine). Furthermore, in order to improve the modeling process, the target is an ideal machine with infinite resources like memory, processor time and program threads. This leads together with the message-orientated communication between the processes (analogous to UML State Charts) to a loose coupling of the CEFSMs. The result is a hierarchically structured, automaton-based model with a message based communication. A recent, more powerful language, but with a much broader focus is *the Unified Modeling Language* (UML). UML builds also on an automatic model based on.

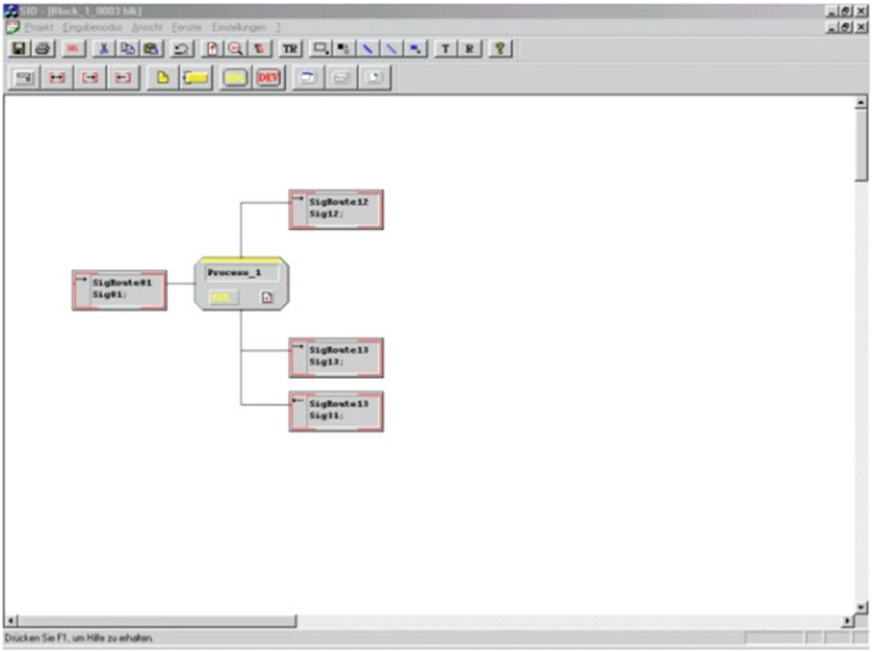

Fig. 1 SDL-block diagram

2.2 Semantic Technologies

In the context of modern information systems as an ontology is the explicit specification of conceptualization of an application area considered [6]. In accordance to the general understanding of information sciences, ontologies are technical artifacts [7–9, 16] which are composed of a vocabulary and the coherent explicit assumptions regarding the meaning of the vocabulary. For the description of the vocabulary, logic-based languages can be used with their most prominent representative, the *Web Ontology Language* (OWL).

2.2.1 The Ontology Language OWL 2

The logic-based ontology language OWL [10] is a W3C recommendation from 2004 with the successor OWL from 2009. One central target of OWL is the description of complex ontologies; for practical use there has to be a balance between the inference and the expressiveness. The widespread standard *OWL-DL*, a predecessor of *OWL-2*, is based on the expressive description logic *SHOIN (D)*. OWL-DL includes the semantics of the class description logic *Attributive Language with complement (ALC) plus transitive roles (r+)*, whereby the class $ALCr+$ is abbreviated with S. Other language elements H (sub role relationships), O (closed classes), I (inverse roles), N (number of restrictions) and D (data types). The standard OWL2 of the W3C has a lot of modifications compared to OWL-DL which became necessary due to practice with OWL-DL. Based on the logic SHOIN considering a number of restrictions, the logic SHOIQ was designed. On this basis, including expansions and language features which influence the handling but not the expressiveness of the dedicated language, the *OWL-2 SROIQ* underlying logic has been developed.

2.2.2 Basic Ontologies

In [11] several types of ontologies were introduced. There is a distinction between top-level ontologies, domain ontologies, task ontologies and application ontologies. Thereby, it has been proven that it is much more effective to separate common knowledge from domain specific knowledge and to store it within top-level ontologies. Basic ontologies, also known under the terms upper ontology, top-level ontology, foundation ontology and hyper ontology describe common knowledge that should be used on all domains and applications. Examples for basic ontologies are *DOLCE*, *OpenCyc* and *Sumo*. *DOLCE* is a result of the so-called *WONDERWEB* project which has been accomplished by Nicola Guarino and his team from 2002 to 2004. This in OWL formulized and in several versions available ontology is still the central pattern for the design for basic ontology approaches. A widespread used basic ontology is *DUL (DOLCE + DnS Ultralite)*.

DUL is a differentiated axiomatized framework which offers all the basic concepts and roles for the modeling of systems such as physical artifacts, abstract etc. The generic approach of DUL allows use in any application area.

2.2.3 Ontology Design Pattern

Ontology Design Pattern (ODP) are modeling patterns which can be suggested as implementation independent solutions for commonly recurring problem classes [12]. ODPs gained prominence in the context of the Description and Situations (DnS) Fontology. DnS is context-sensitive description of types and relationships while expanding the descriptive characteristics of DOLCE. Content ontology design pattern are primarily discussed in the context of DnS.

2.2.4 Sensor Ontologies

From the abundance of the currently available sensor ontologies, the exemplary representation of the W3C Semantic Sensor Network Ontology (SSN) is best suited for the creation of AAL ontologies because this ontology is a direct result from the analysis of most of the relevant existing sensor ontolgies. From the work of the OGC Sensor Web Enablement under the name [14], a service-oriented architecture and and a couple of standards have emerged. Inter alia there are four languages, which deal with capabilities of sensors, the measurement variables and other characteristics. Besides the classification of sensors and a process-oriented view of measurement systems, interoperability and data exchange are discussed. However, the semantic interoperability for the construction of self-organizing sensor networks is still not supported. The goal of the SSN—W3C Semantic Sensor Network Incubator Group was to create an abstract view of sensor networks. The main objectives of the work were the self-organization in terms of installation, management and retrieval as well as the understanding of a sensor network and its data by services of higher order. In the first stage of the development, an ontology for the representation of single sensors and complete networks for the usage within web applications was designed. The classification of the sensor components themselves as well as the coherent conclusions regarding their properties, related measurement values, the origin of sensor data and the orchestration of sensor nodes is supported by the development macro tools. It is aimed to adapt the existing standards of the Open Geospatial Consortium (OGC) . The SSN ontology is based on domain ontology as a basic ontology. It is an alignment of the SSN ontology and the DOLCE UltraLite Upper Ontology to normalize the ontology structures. In addition, it is aimed to integrate other ontologies and linked data resources. Sensor networks are completely different from IT systems (e.g. SOAs). Therefore, for the completion of the SSN ontology it is essential to regard the event driven characteristics as well as the spatialtemporal context of the data to consider. In addition, the ontology does not cover specific application domains, measurement units, time and space, and mobile aspects.

3 Methodology

Actually in respect to the state of research, there are no common techniques for the description for AAL technologies which cover the entire spectrum of the necessary technologies for all possible AAL applications. For this reason, in the following an approach is proposed, which can serve as a graphical representation of integration profiles.

3.1 Block Diagrams for Integration Profiles

After a survey and deep analysis of existing AAL-systems and components, a function block based description method for heterogeneous distributed systems was proposed by the RAALI-project (refer to Fig. 2) which implements graphical representations for services, actuators or sensors. Thereby, the general function block (FB) is only defined by input–output relations similar to simple mathematical functions with parameters and return values, and serves as a blueprint for much more complex structures e.g. block types as sensors or HCIs. Expanding the general FB by a sensory component, graphically characterized by an additional input, the function block for a sensor is fully described. An actuator is described in the same manner—only the direction of the input–output indicating arrow is opposite and the index switches from S (sensor) to A (actuator). In the case of a user interface (HCI—Human Computer Interface), there is a bidirectional arrow that symbolizes both user input and system output. If the feedback path is removed, the HCI is reduced to an actuatory or a sensory component. Besides the pure graphical representation each component is described in detail a separate report. Through the connection of the inputs and outputs of the individual components, it is possible to arrange them into a logic and functional sequence. This requires conformity of the respective affiliated inputs and outputs. To reduce the complexity of real scenarios by a higher level of abstraction, the encapsulation of functional related components through super blocks is beneficial. By this way, it is possible to aggregate individual functions to complex structures only by the adjustment of the input–output relationships. For additional details about the use of function blocks refer to [15]. The selected form of description is available by a informal representation. For the introduction of automatic assistance functions as design automation or the self-configuration of AAL-systems, it is necessary to gain a formal representation of AAL-integration profiles.

3.2 Engineering Process of an AAL-Ontology

In addition to the block diagrams for the AAL-integration profiles presented in Sect. 3.1, as an output of the project Standardisierung eines semantischen

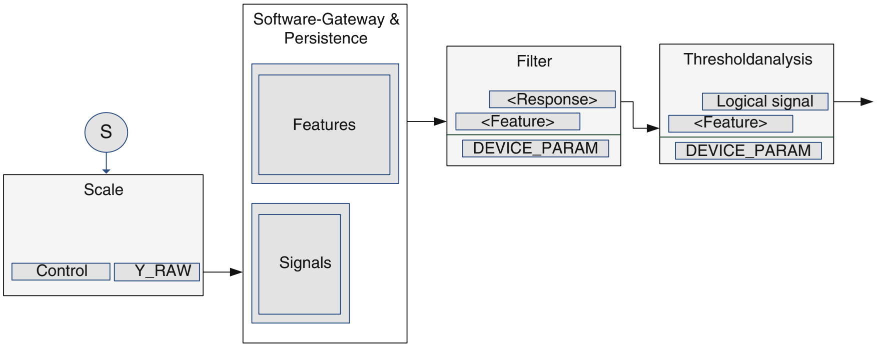

Fig. 2 Block diagrams for AAL-integration profiles

Laufzeitsystems zur Foerderung der Interoperabilität von AAL-Komponenten a formal representation has been proposed. Thereby, the expertise of the included ontology engineers is as important as the involvement of domain experts who hold the knowledge about the area to be modeled. In similarity to the software engineering area, diverse engineering approaches focused on interdisciplinary development processes have been established. An OTK methodology for the design of ontology based knowledge management infrastructures based on CommonKADS was proposed by [16, 17]. In accordance to classical project management methods the ontology engineering process consists of the consecutive steps feasibility study; kick off, refinement, evaluation and application and evolution. Usually, this process is iterative and executed by multiple times. In the following the development of the prototype is described. For this reason, the region under examination is restricted to a non-representative group of users, stakeholders and experts.

3.2.1 Feasibility Study

During the Feasibility Study possible applications and solutions were identified and analyzed due to their applicability and relevance for practice by the users and stakeholders. The following applications have been selected as the basis for much more complex scenarios:

- Device Discovery and Selection.
- Data Discovery and Binding.

In order to preserve the proximity to existing components at the beginning a sensor was modeled instead of a general function block. The core element of the feasibility study is the collection of data sources. Own project experiences and conducted expert interviews allow a reduction of the set of relevant sensors for AAL. The DIN standard 1319–1 .. 4 [19] provides valuable information regarding the general characteristics of sensors, measurement methods and data analysis, allowing a structural point of view to such systems. In particular for sensor ontologies, there exists a lot of information from the OGC and the W3C Sensor Network Incubator Group. As the same in the area of AAL, it is aimed to abstract complex sensor network infrastructures and their binding to IT-systems also as the encapsulation of services. While the actual prototypical engineering process is based more on methodological sources, future approaches primarily will integrate expert knowledge, manufacturer knowledge and product knowledge.

3.2.2 Kickoff-Phase

In accordance to [20] an ontology requirements specification document (ORSD) was provided at the beginning of ontology development.

Objectives and the Role of the Ontology: It became apparent that two different views at one and the same function block are required. The system integrator has a purely conceptual view at a function block. At this point it is important to note that the system integrator is thinking about a specific measure and description for the entity heart instead of the biological unit itself including parameters which describe the coherent sequential values of heart beat. This means, it is only important to distinguish between different measurement and description concepts and to refer to associated data bases. Following concepts were selected for the reference of sensory databases. The concepts (see Table 1) are incorporated into a so-called description pattern—one ontology design pattern which is suitable to represent descriptions consisting of manifold concepts.However, automatic support functions require a pure technical view which describes the physical device completely—this fact implies a description of device properties, parameters and values, measurement processes and the communication interfaces. Contrary to the conceptual view which describes the intention of a function block, the technological view is dedicated for the provision of detailed information for the automatic knowledge processing (e.g. for the identification of

Table 1 Concepts from the integrator's perspective

Concept	Example
Domain	Building automation
Procedure	Conditions, plan
Aim of measurement	Detection of residents
Target value	Status variables (door closed)
Location	Room
Measurement frame	5 h campaign
Platform	EnOcean
Operation model concept	Measurement principle
Interface concept	wired/wireless communication, 802.15.1 BT, 802.15.4/Zigbee
Product line-up	wired/Identiy of the manufacturer, product family

interoperable sensors which deliver data to a processing function block. Both views are mutual complements.

Methodology: The main structural idea deals with the description of the various function blocks by ontology modules. Thereby, a function block is a graphical representation of an ontology module. Thinking about an orchestration of different functions blocks covering a scenario or in particular an AAL-application, this array of blocks is equivalent to the ontology with additional meta-information. For the modeling, the usage of OWL 2 and DUL − DOLCE + DnS Ultralite (for the basic ontology) was selected. Based on the work of Gangemi [12] each function block is projected by a so-called ontology design pattern (ODP). In order to improve the interoperability of parallel approaches all ODP-concepts and ODP-roles are derived from the basic ontology DUL (DUL-Alignment). The last step consists of the differentiation of the function blocks. The semantic part of work is done by a device specific implementation of sensor-ODP.

Competency Questions: In addition to non-functional demands the specification of competency questions (CQ) is decisive for the success and impact of the whole engineering process (refer to Table 2). The competency questions give a first impression about the necessary vocabulary, its classes and roles. Due to the questions it becomes clear which answer shall be derived from the upcoming ontology. This is exactly the point where the SSNs had been expanded [13].

Concept Retrieval: Finally, the ontology relevant objects are derived from the responses to the competency questions and the questions itself. Due to the fact that the W3C SSN-ontology has been adapted to this procedure, the vocabulary exists of integration oriented concepts and roles.

Refinement-Phase: One important step in ontology engineering is the refinement phase, essentially for the transform of semiformal ontology into a machine-recognizable representation. In order to formalize the ontology, two fundamental methods are recommended by [16, 17]: The Top-Down method as well as the Bottom-Up-method. The Bottom-Up-method is based on procedures and tools for the automatic text analysis. If documents contain all the system relevant information, the semi- or fully automatic generation of taxonomies leads to the complete summary of concepts of a domain. Due to the fact that all possible concepts will be regarded, a consecutive process much more focusing on the aspects of central issues will be executed which induces many efforts due to system complexity. For this reason the bottom-up method is not used. On the other hand, the

Table 2 Competency questions

Use case class	Competency questions
Data discovery and linking	Which observations are sufficient to criteria as domain, task, measurement object, location, time window, platform, operation model, network interface and identity
Device discovery and selection	Which devices are sufficient to criteria as domain, task, measurement object, location, time window, platform, operation model, network interface and identity

preferred top–down approach leads from an abstract view on the emerging knowledge model to an increasing specialization of concepts and roles.

In this context, the reuse of established basic ontologies like DUL as well as the W3C domain ontology SSN is beneficial for practical usage. This condition allows the construction of self-consistent, evaluated conceptual framework which can be expanded systematically by the consideration of the competency questions. For our approach, we selected a couple of diverse ODPs including the DnS pattern as the most important one. The DnS-pattern (refer to Fig. 3) consists of a distinct pattern describing situations (S-ODP) and a description pattern itself (D-ODP). The D-ODP is used to associate concepts (DUL: Concept) by the aid of the role (DUL: uses concept) with a context, represented by (DUL: description). It can be interpreted as an abstract, conceptual description of a context e.g. a sensory data source. The S-ODP is used for the technological view. In the S-ODPs, the mapped situation is expressed by a sum of entities (DUL: Entity) under the usage of the role (DUL: is setting for). The DnS-ODP is a composition of both pattern and relates a description (DUL: description) to a situation. Thereby, it is possible to relate single entities of the S-ODP to concepts of the D-ODP and associate them with a specific context. The competency questions typical for this pattern are:

- Which sensor situation complies with the sensor description?
- Which sensor descriptions can be accomplished by a sensor situation?

The classes and roles from the W3C SSN ontology were applied due to compatibility aspects (refer to Fig. 4). In order to improve the conceptual view (from

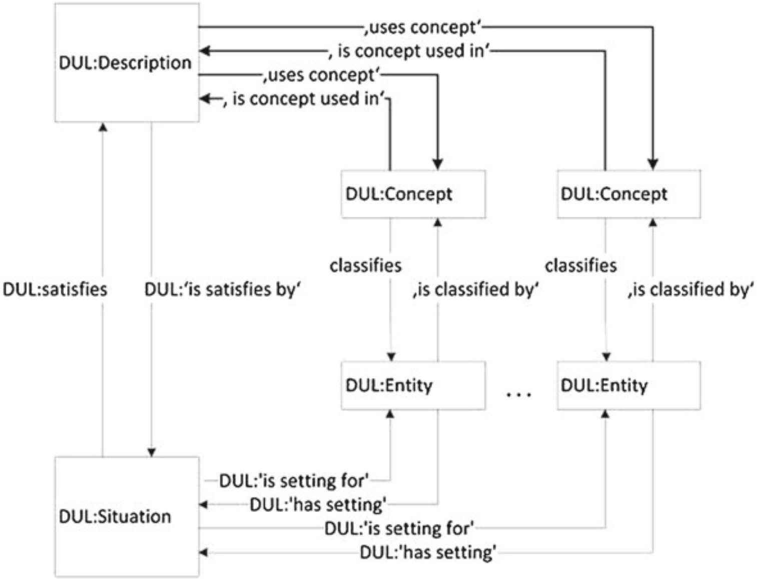

Fig. 3 DnS pattern (www.ontologydesignpattern.org)

AAL-system integrators), additional classes have been introduced which were derived from the class DUL: Concept (refer to Fig. 4—dotted area). The introduced classes are not physical objects and therefore not derived from DUL: Physical object. The classes care about the process of information exchange and cover universal properties of sensor components and their data for the implementation within the context itself. The concept Domain Concept relates the entity feature of Interest to a specific context.Through the D-ODP, it is possible to integrate the instance of a usual, network-compatible scale within the context of the application dry-weight monitoring—the instance gets a context related role. Thereby, entities can be embedded within various situations and get a context independent meaning. If the entity telephone is an integral element of an emergency indication system, there exists also an entity for other possible contexts (account of telephone charges). But however, by the classification of the universal component telephone through the concept emergency indication devices, the telephone gets its role within the context emergency indication system. In the following section the new concepts from the prototypical engineering process are introduced. In particular, it is expected that the knowledge will be extended by repetitive runs of the process considering domain experts. The concepts are therefore only a basis of discussion. Contextualization of measurement objects:

- *Domain Concept* specifies a domain within a finite set of AAL-domains (BA, telemedicine). Domain Concept contextualizes the SSN class Feature of Interest, which super class can be either DUL: Event or DU: Object. By this way, Domain Concept associates an arbitrary object or event with a domain.
- *Task Concept* contextualizes the SSN class Feature of Interest with the focus on the planning of the measurement campaign. Best practice suggestions from manufacturers are expected (specific application regarding exact rules for the handling).

Contextualization of object properties:

- *Objective Of Measurement Concept* relates properties of a measurement object to the target of application (The detection of residents in a room through the evaluation of BA sensors like door contacts).
- Objective Of Measurement Concept describes the result of the measurement or the feature extraction process (possibly complex processes executed over different data processing layers).
- *Physical Quality Concept* associates the properties of a measurement objects with the characteristics of the measurement process itself.

Contextualization of the sensor:

- *Location Concept* is responsible for the spatial definition of the operation area. Possible instances are indoor or outdoor. A fine granular differentiation is planned within the taxonomy itself.

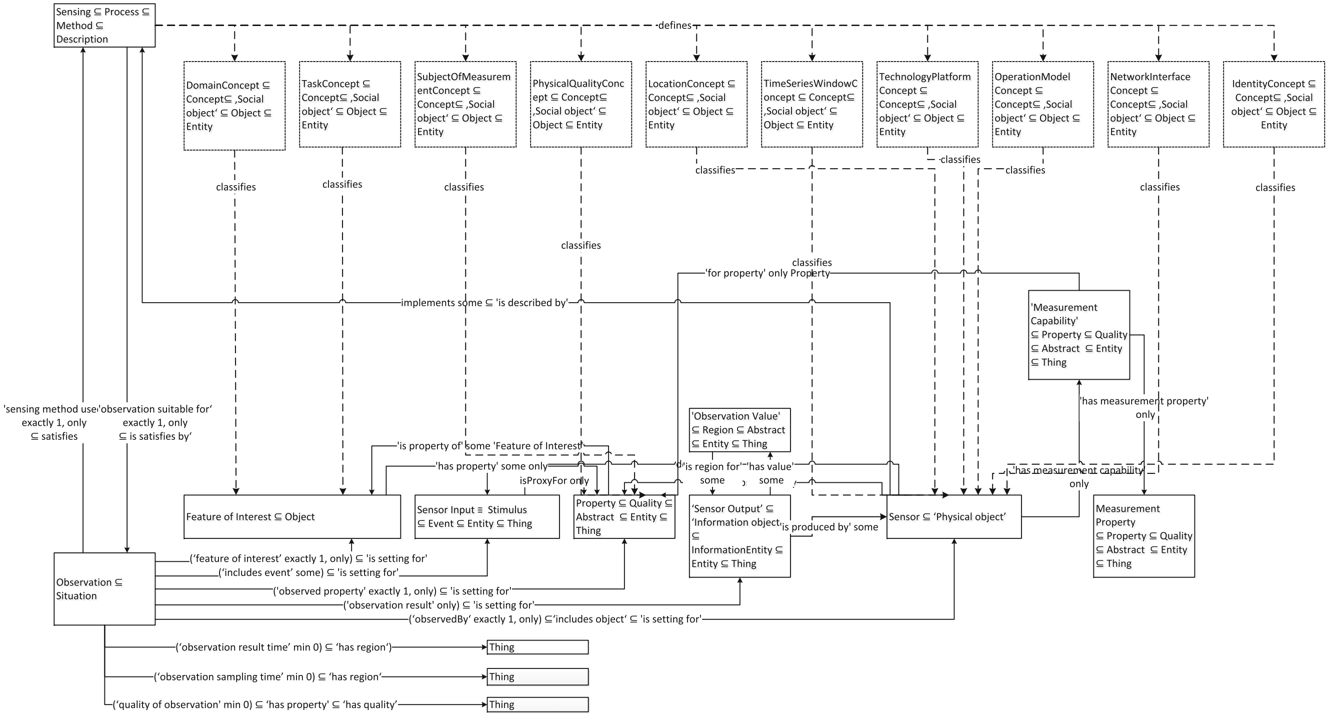

Fig. 4 AAL-sensor ontology (SSN [13] and AAL D-ODP

- Time Series Window gives information about the data properties regarding time. This is important for the interpretation of dynamic processes and various contexts.
- *Technology Platform Concept* is a concept for the limitation of the inference based search processes. The examination area is restricted to a subset of available AAL-components which can be associated to a distinct technology platform. The concept contextualizes DUL: Sensor, a physical object executing real measurement processes. Furthermore, the concept is appropriate for the description of home automation concept from a systemic perspective. This means that a building automation system of a manufacturer X which implements LON and an IP-based control level and provides a BACNet-IP interface is mapped to a sensor in accordance to the BACNet-standard. This implies that larger infrastructures can be subsumed by data points, named by the term sensor. For real scenarios, it is obvious that specific implementation characteristic should be considered in practice.
- *Operation Model Concept* describes concepts for sensor functions, result classes and working principles Network Interface Concept contain interface concepts for e.g. the wireless communication. In particular, the restriction to standards enables a limitation of the examination area.
- *Identity Concept* enables the system integrator to search for components of single manufacturers or second source products during the design of non-interoperable AAL-systems. Thus, the Identity Concept is another approach for specialization outside the taxonomy.

Formalization: For following reasons it was possible to skip the usual first steps in ontology development (creation of the taxonomy):

- A basic ontology following DUL was used.
- A complete domain ontology was available (SSN).

Instead, the taxonomy has been extended to the classes described above. All necessary parts were taken from the DUL-vocabulary. Considering the upcoming meetings with domain expert, any prognoses regarding new concepts cannot be made. But however, new concepts will be specializations of super concepts (e.g. contained in DUL). The refinement phase is closely associated with the evaluation phase. Detected errors from the different evaluation processes (user-, technological- or ontological view) enter a cyclic repetition of the refinement phase for successive improvement.

4 Discussion of Results

After the completion of the first prototypical refinement phase, as an integral part of an AAL-ontology a formalization of a sensor function block was derived. According to technological aspects the ontology module was analyzed and will be evaluated through subsequent expert workshops. Referring to [16] evaluation approaches regarding the technical view, the user position resp. the application view and the ontological view (deployment view) will be executed. Analysis and evaluation from the technological perspective: In addition to the analysis of linguistic conformity several modeling problems regarding the satisfiability of class definition have been fixed by the aid of different inference machines. The analysis of the runtime properties of the coherent inference processes, of consumed memory and the scalability due to the growth of A- and T-box is the next step after finishing the expert workshops and the implicated model modifications and instantiations of real products. The start of the evaluation of the prototype regarding the user perspective is planned for the first workshop. There is the question whether the defined ontology meets the requirements gathered in the previous steps. At this point it is beneficial to refer to the central ORSD and the related competency questions. The result of the workshop is still uncertain. Analysis and evaluation from the modeling perspective: An acclaimed approach from 2000 for checking the consistency of ontological taxonomies is the OntoClean method. OntoClean works with expressions from the classical philosophy (e.g. essence, rigidity, identity, unity) and proposes the establishment of a meta-notation for the ontology classes. A meta-notation expands every conceptual part of an ontology through the appendage of coherent properties due to consistence criteria. In particular for concepts which are interrelated by super/-subclass relations. For further details refer to [21]. The analysis of taxonomies and their evaluation will be executed after the integration of the expert workshops.

5 Conclusion and Outlook

The research results of the BMBF-project RAALI provide a graphic based description approach for the deployment of AAL-systems. But however, for the technical support in accordance to the principles of design automation, it is indispensable to formalize the RAALI integration profiles. Therefore, this chapter focuses on the prototype of an ontology engineering process which is determined to collect and aggregate AAL-specific knowledge through expert interviews and workshops, ending with the formalization of the gathered information. After a successful test case, the proposed ontology engineering process will be repeated with experts from the area of building automation, telemedicine and telecommunication. By this way, a representative impression of the expert knowledge adopting the involved disciplines of AAL can be achieved and formalized to an ontological representation. The processes will be repeated several times to increase the quality of knowledge significantly. It is assumed that these expert workshops end in June 2013 in form of a proposal for the standardization of AAL-ontologies.

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