An Ontology for Interoperability: Modeling of Composite Services in the Smart Home Environment

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Abstract. A developed service for smart home environments controls and coordinates a variety of appliances to influence physical environmental parameters selectively and to create a pleasant and activity appropriated room atmosphere. In the meaning of this paper this kind of service is defined as a composite service. There are several approaches to map services in ontologies. But these ontologies are not able to map composite services as they are introduced here. In this paper a possibility for mapping composite services with an ontology is presented. The composite services are defined on a devices landscape, with devices using exclusively DC voltage. The mapping of the composite services is done to promote compatibility to other systems. The paper's scope is to show recent research activities and their partial results. Because the work is still in process final results are outstanding.

Keywords: Composite services · Interoperability · Ontology · Smart home

1 Introduction

In the field of smart home, it is a general goal to bring more intelligence to the automation systems. [1] Moreover, the efficiency in using energy should be increased. One approach is using photovoltaic systems (PV systems). With these systems the consumer can generate his or her own power. The generated electricity is fed into the own and surpluses in the public network. Currently, the DC voltage (direct current) generated by a PV system is alternately directed into AC voltage (alternating current). But many appliances in households based on DC voltage. So AC voltage is rectified back in the device's power supply. These inverter and rectifiers create significant energy losses. In this respect, the direct use of DC voltage in the power grid is interesting.

In the project EGNIAS at the University of Applied Sciences Zwickau the potentials of using DC voltage in the smart home (SH) environment were examined. Therefore appliances, which are used in SHs and based on DC voltage, have been identified. On this device landscape services have been defined. These services are

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"composite services", which can directly influence physical environmental parameters. The focus in this paper is, how these services can be represented in an ontology and thus made available to other processes. For this, firstly the concept of a "composite service" is presented. Then the existing research contributions and ontology approaches are shown. From the results of this inspection, the need to conceive an own ontology for the "composite services" is demonstrated. The developed concept will be presented and applied for a specific service.

2 Composite Services

First, it is necessary to identify appliances which can be operated with DC voltage. It turns out that these can be found mainly in the field of low voltage. According to the Energy Information Agency (EIA), the fastest growing portion of residential electricity use is consumer electronics and small appliances [2]. Therefore, the selection of the units has focused on this sector. Exceptions are the selected lamps. LED lamps are also suitable for the project, which is why they were included. So among other things the device landscape contains a phone, a tablet PC, a radio and a variety of LED lamps. On this basis the "composite services" were defined. The aim is that the room can be set to different use alternatives. Special attention must be set to the subjectivity of human perception assets. For example, a person's perception of the same light intensity is different in various situations. This contrasts with the system's objectivity that is controlled with absolute values. Therefore, the user needs must be analyzed, interpreted and integrated accordingly in the services. For example, the illumination of room areas can be differentiated. In this regard manual changes of the user are stored and used as a standard for the next application. Thus, the services are customizable.

A composite service is defined as a process to influence physical environmental parameters selectively to create a pleasant and activity appropriated room atmosphere. So with a composite service not a single device is controlled but a variety of devices is coordinated. The services are therefore not fine-grained, which represents a new approach in building automation.

The services will now be displayed in such a way that it is compatible with existing approaches. The design of the defined services shall be formally mapped. This promotes compatibility in such a way, that the composite services can also be integrated into other room control systems.

3 Related Literature

In the topic smart home there exist a number of research activities, which are focused on services.[1]

[1] As in the project EGNIAS energy efficiency plays a big role in the smart home environment. For example in [3] an empirical study which deals with this issue and which is based on an analysis of user activities is presented.

Moji Wei et al. [4] present an “Ontology Based Home Service Model”. That is a model to retrieve and invoke services according to user’s needs automatically. But firstly needs must be determined. The contribution mainly deals with how these needs can be determined. The services, which are retrieved, include the retrieval of a single device. However, the here defined composite services do not meet this fine-grained structure and thus they represent a continuation of the approach of Moji Wei et al.

Mobility and heterogeneity are characteristics of many devices in the SH. In order to manage these devices efficiently, the system CASSF (Context-Aware Service Scheduling Framework) [5] filters out and offers suitable services. This is done according to the task requirements (TR) and serves an improved user experience and content adaptation. Therefore the devices and their functions were mapped in an ontology, a context-sensitive service selection program was developed and a method for content adaptation was proposed. This shall achieve an enhanced user satisfaction. In CASSF functions are derived from the user’s needs. This is the basis for the services. The analysis of the needs was based on Maslow’s hierarchy of needs [6]. The needs are interpreted with the aim of providing an appropriate service. But in the here presented concept it is the point that the user tells the system his planned activities and expected that the room sets on it, for example, by an appropriate lighting scenario. Which scenario is to provide in a situation was indicated to the system within the customizing. So in the concept the analysis of needs is not done by the system. This distinguishes the CASSF approach from the shown one. However, considering that at the same time there could be several people in a room, which have different requirements, these requirements have to be reconciled and the related services have to be combined. For this service combination CASSF could provide a solution approach.

The approach presented by Yung-Wei Kao and Shyan-Ming Yuan [7] is based on the theory that a user in a smart home thinks semantically. His request to the system might be: “I want to turn off all the lights on the second floor.” To illustrate this in an ontology USHA (User-configurable Semantic Home Automation System) and a self-defined markup language SHPL (Semantic Home Process Language) were developed. SHPL is able to semantically link the information “all” or “none” and the concept of belonging [7]. Thus “I want to turn off all the lights on the second floor” can be implemented.

The presented approach goes on one step further in this relationship. The user does not need to selectively turn on or off the lights and appliances. Instead, he tells the system only, which is his planned activity and the room sets on it automatically. Therefore the devices are addressed differentiated. For example, all the lamps of a region are turned on, but only with a power of 25 %, except lamp XY, which is turned on with full power. With our approach this central aim of context-aware systems is achieved. Even the following circumstance is feasible: If the environment due to external influences is already so bright that the full power of lamp XY does no longer increase this brightness, the lamp does not need to be turned on or only with a lower power.

4 Basic Ontologies

The conception of the defined composite services shall be formally mapped. This is to promote compatibility in such a way that the design can also be integrated into other systems than the control room of the project. For such a mapping ontologies are very useful. There are a number of different ontologies. But all were situated within a particular context. In this chapter two ontologies are presented, whose contexts have a high degree of relationship to the described developed services in the smart home environment. The aim is to illustrate the ontology's contribution to map the presented composite services.

Using DogOnt [8], modeling an intelligent, automated environment with the devices, their status, functions and messages, as well as the architecture is possible (Fig. 1).

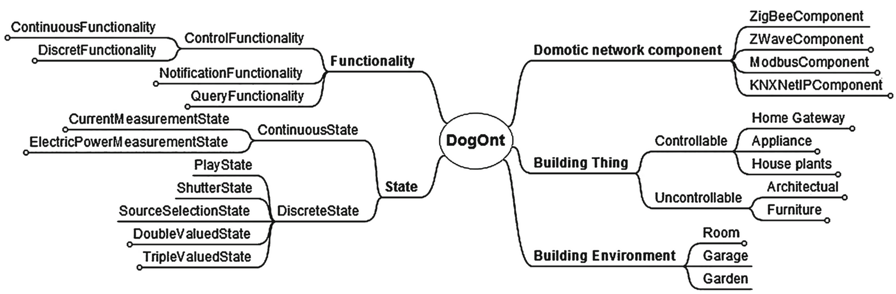

Fig. 1. Overview of the DogOnt ontology (source: based on [5] p. 794)

It seems to be the most complete ontology for modeling building components. It includes a wide taxonomical organization of controllable devices (appliances, home plants and home gateways), including their functions (control, notification and query) and notifications. However, no description of hardware features of the devices is possible. This is important for example to determine the quality of the offered service [9]. In addition DogOnt is not able to map composite services, as here defined. Although it contains commands by which the command to individual devices can be mapped. But composite services include a variety of commands to a variety of devices. The ability to map this instruction bundle, which is furthermore derived from corresponding input factors, is missing in DogOnt.

Instead Owl-S [10] is able to describe scenarios and services. It makes possible to discover, invoke, compose, and monitor Web resources to offer particular services and supports to do it with a high degree of automation. In OWL-S services with an input and an output are defined (Fig. 2).

This approach is picked up by Davy Preuveneers and Yolande Berbers [11]. They developed the ontology CODAMOS. They use this ontology in service-oriented computing context. But web services do not include the functionalities which comprise the here defined composite services. However, they provided a decisive approach to the development of an ontology which is able to map these composite services.

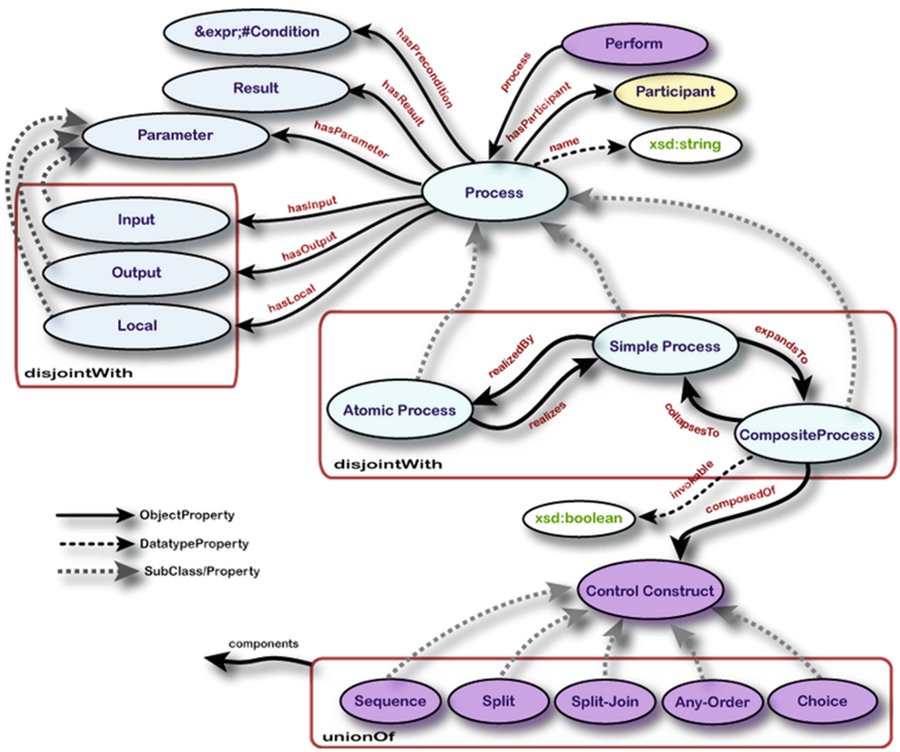

Fig. 2. The process ontology of OWL-S3 (source: http://www.w3.org/Submission/2004/SUBM-OWL-S-20041122/)

5 Research Contribution

The representation of something real in the meaning of ontologies includes a conceptual layer and identities layer. In the conceptual layer the general construct with corresponding relations is shown. The identities-layer is a parallel level to the conceptual layer. In the world of ontologies identities are the specific properties of the object. Therefore in the identities layer the real objects, based on the structure of the conceptual layer, can be mapped.

The following part shows how a non-fine-grained composite service can be mapped in ontologies. Therefore a concrete example of a composite service is presented. Subsequently, the conceptual layer is explained, therewith such a non-fine-grained service can be mapped. Finally, the presented service example is mapped on the identity layer.

In Fig. 3 there is to see a schematic representation of the model room, which is constructed by us. The lamps are controlled directly and the devices by means of the sockets. Based on this devices landscape the services have been defined.

As an example the welcome_service shall be mapped. The welcome_service is the basic service of the control. The aim of this service is to illuminate brightly the entire

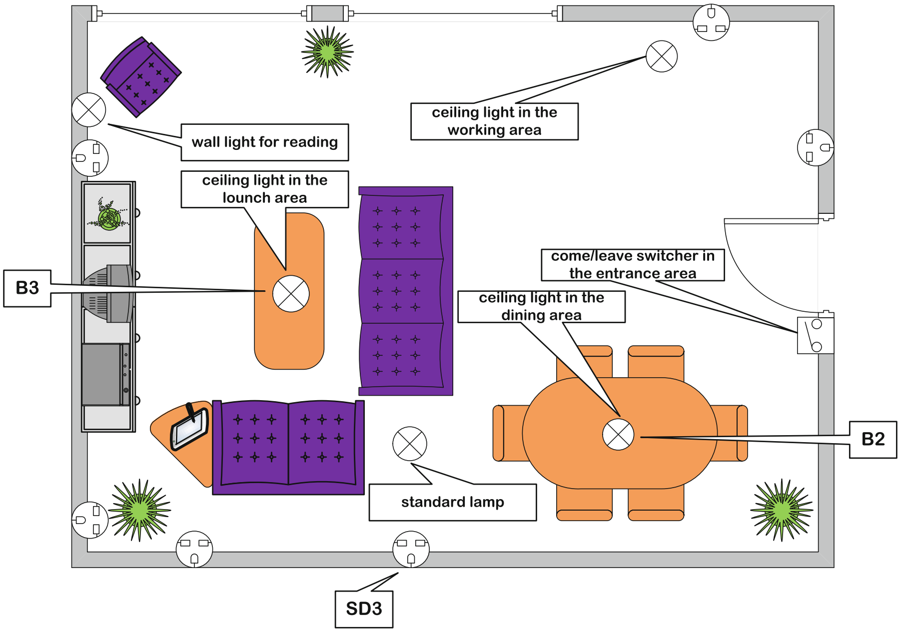

Fig. 3. The model room

room. Therefore the dimmable lamps over the dining table (B2) and over the lounch table (B3) are switched on with full power. The floor lamp next to the couch is also turned on. This is connected to a socket (SD3), which must be activated.

Because DogOnt is basically able to represent the devices and components in a SH, it makes sense to extend this ontology. To incorporate the notion of a process, the process design of OWL-S can be taken up. For the input and output of the services DogOnt provides its own relevant states and commands.

The conceptual layer:

A service is a subclass of a process. A process has an input and an output. The input consists of the room_usage_type, the light_intensity_state and a brightness_reference_state. The room_usage_type and brightness_reference_state are a discrete_state. The various room-usage-types in the EGNIAS- project are “welcome”, “dining”, “working”, “reading”, “music” and “tv”. These are variables of the room control. With them the planned activities of the user are stored in the system. The brightness_reference_state is a parameter which is required for room control. A brightness_reference_value is associated with it. The light_intensity_state is already defined in DogOnt.

A process generates commands. Thus commands are the output of a process. Commands are also defined in DogOnt. A subclass is added here: the *step_up/down_command*. This compares a *controllable_building_thing*’s *state_value* with a *reference_value* and adjusts the *state_value* to the *reference_value*.

The commands affect an object of *controllable_building_thing*, which is represented by the property *for*.

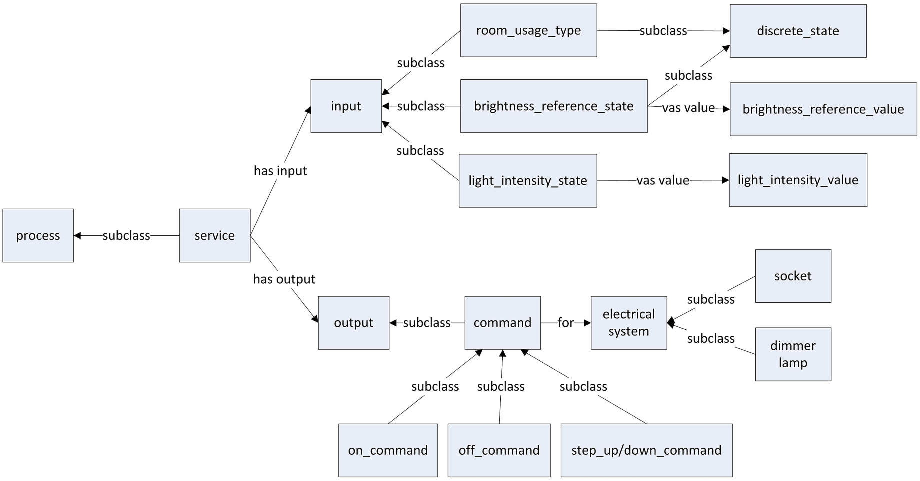

Fig. 4. The ontology's conceptual layer

Figure 4 shows this construction in the conceptual layer.
The identity layer:

The welcome_service needs the room_usage_type welcome, the brightness_reference_state for the dining area (brightness_reference_state_dining_area) and the lounch area (brightness_reference_state_lounch_area) with the value 100 (percent) as well as the light_intensity_state for these areas (light_intensity_state_lounch_area, light_intensity_state_lounch_area) as input. The values of these last two states are provided by brightness sensors. The welcome_service's output contains of an on_command for the socket (on_command_SD3), step_up/down_commands for the dimmer lamps (stept_up/down_command_B2, step_up/down_command_B3) as well as off_commands for all other sockets and lamps. Fig. 5 shows the identity layer for the welcome_service.

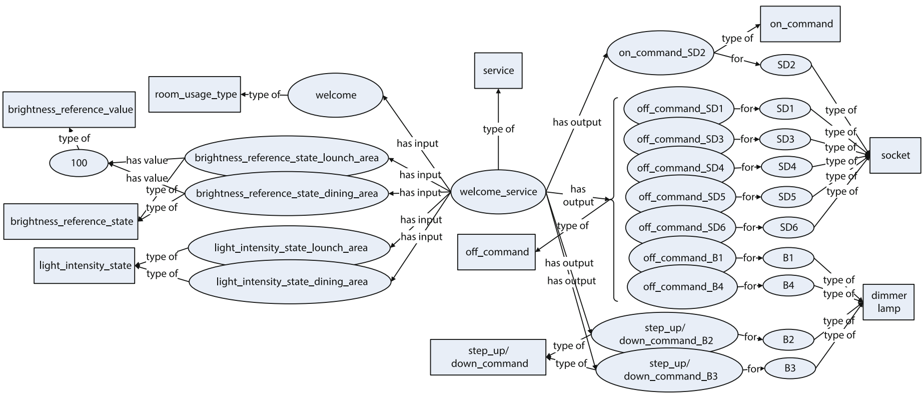

Fig. 5. The ontology's identity layer

6 Conclusion and Further Work

The starting points of this paper are two general goals: more intelligence and more energy efficiency in the Smart Home. In the project EGNIAS these aspects were picked up and linked. The result of the project activity is a model room. This model room is equipped with appliances whose functionality is based on DC voltage. A power grid was implemented, which supplies the appliances directly with the appropriate DC voltage. On this device landscape composite services were set up. A composite service is defined as a process to influence physical environmental parameters. By choosing a room usage type (dining, reading, working …) the room shall create a pleasant room atmosphere that is appropriate to the user's planned activity. So composite services are not fine-grained, because a variety of devices is coordinated to each other.

To make the whole system compatible to other systems the composite services were mapped in an ontology. It was realized by picking parts of DogOnt and OWL-S. The reuse of existing ontologies reflects the desire for compatibility. In DogOnt the concept of a smart home is mapped extensively. OWL-S provides the design of a process, but relates to computing services. Therefore, the concept of a service in OWL-S has to be adapted to the concept of a composite service. It also was combined with elements of DogOnt. So these two ontologies have been linked and a composite service can be mapped.

Because the device landscape's control is not yet flexibly variable, the current implementation of services can be classified as static. Each device has to be introduced manually to the system. This still does not meet the dynamism with which a user is acting in his apartment and within he should be supported. Further research activities will therefore deal with the problem, how new devices can be dynamically inserted into the system. A solution could be a communication via UPnP. The devices' required information could be stored in the cloud and loaded from there as needed in the system. Furthermore, a possibility to accordingly extending of existing services or to defining new services has to be found.

References

1. Bregman, D.: Smart home intelligence - the eHome that learns. Int. J. Smart Home **4**(4), 35–46 (2010)
2. http://smartgrid.ieee.org/june-2013/881-is-dc-s-place-in-the-home
3. Nguyen, T., Aiello, M.: Energy intelligent buildings based on user activity: a survey. Energy Build. **56**, 244–257 (2013)
4. Wei, M., Xu, J., Yun, H., Xu, L.: Ontology-based home service model. ComSIS **9**(2), 813–838 (2012)
5. Liang, Y., Zhou, X., Yu, Z., Wang, H., Guo, B.: A context-aware multimedia service scheduling framework in smart homes. EURASIP J. Wirel. Commun. Netw. **2012**, 67 (2012). http://jwcn.eurasipjournals.com/content/2012/1/67
6. Maslow, A.H.: A theory of human motivation. Psychol. Rev. **50**(4), 370–396 (1943)
7. Kao, Y.-W., Yuan, S.-M.: User-configurable semantic home automation. Comput. Stan. Interfaces **34**, 171–188 (2012)

8. Bonino, D., Corno, F.: DogOnt - ontology modeling for intelligent domotic environments. In: Sheth, A.P., Staab, S., Dean, M., Paolucci, M., Maynard, D., Finin, T., Thirunarayan, K. (eds.) ISWC 2008. LNCS, vol. 5318, pp. 790–803. Springer, Heidelberg (2008)
9. Grassi, M., Nucci, M., Piazza, F.: Ontologies for smart homes and energy management: an implementation-driven survey. In: Proceedings of the IEEE Workshop on Modeling and Simulation of Cyber-Physical Energy Systems MSCPES (2013)
10. Martin, D. et al.: OWL-S: Semantic Markup for Web Services. W3CMember Submission, 22 November 2004. http://www.w3.org/Submission/OWL-S/
11. Preuveneers, D., Berbers, Y.: Automated context-driven composition of pervasive services to alleviate non-functional concerns. Int. J. Comput. Inf. Sci. **3**(2), 19–28 (2005)