SmartEnv Ontology in E-care@home (ShortPaper)

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Abstract. In this position paper we briefly introduce SmartEnv ontology which relies on SEmantic Sensor Network (SSN) ontology and is used to represent different aspects of smart and sensorized environments. We will also talk about E-carehome project aiming at providing an IoT-based health-care system for elderly people at their homes. Furthermore, we refer to the role of SmartEnv in Ecarehome and how it needs to be further extended to achieve semantic interoperability as one of the challenges in development of autonomous health care systems at home.

Keywords: SmartEnv Ontology · E-Health · Semantic Interoperability.

1 Introduction

In the era of the Internet of Things (IoT) and advances in sensor technology, smart environments and their applications are becoming more ubiquitous. By smart environments we mainly refer to sensorized environments that provide domestic monitoring and cognitive assistance services for their inhabitants. The Semantic Sensor Network (SSN) ontology developed by the W3C Semantic Sensor Networks Incubator Group (SSN-XG) is a generic representation model to describe sensors, observations and their related concepts [2,3,4,5]. Using such generalized ontologies facilitates the process of design and development of sensor-based computational systems such as applications of smart environments.

In this work which is a position paper, we briefly introduce the SmartEnv ontology which relies on SSN, as a model suggested to represent different aspects of smart environments. We then discuss why and how SmartEnv needs to be extended to achieve semantic interoperability in the health domain. It is worth mentioning that the SmartEnv ontology has been published as an ontology description article [12] but has not yet been presented to the community.

After a brief introduction to SmartEnv, we also introduce *E-carehome* project as one of the use cases of SmartEnv in the health care domain. A current vision in the area of ICT-supported independent living of the elderly involves populating the home with electronic devices i.e. sensors and actuators, and linking them to the Internet. In *E-carehome* creating such an Internet-of-Things (IoT) infrastructure is done with the ambition to provide automated information gathering and processing on top of which e-services can be built. At the end, we suggest how SmartEnv can be extended to provide semantic interoperability which is required to bring health care services to patients' homes.

2 SmartEnv Ontology

In order to support the use of artificial intelligence techniques for automating the provision of different services in smart environments, it is necessary to describe the capabilities of the various aspects of such environments. These descriptions that have been studied in the literature [6,7,8,9] include physical aspects (e.g., the structure of the environment, sensor network setting or entities), as well as conceptual aspects (e.g., events or activities of the users), and can be modeled in ontologies. The details of the literature study can be found in [12]. During the requirements analysis process, we considered a number of (conceptual) aspects of smart environments to be covered in the ontologies:

Observation/Sensing Observing of an object or a place is the main motivation why the environment is sensorized. A representation model is required to answer questions such as what can be observed by a certain sensor? To what object is a sensor attached? What is the location of the object, and what does the sensor measure? Can the sensor or its holding object move?

Agents Agents (e.g, inhabitants of a home) are the main characters whose activities, locations, or more specific parameters such as safety and health are usually the main reason behind any observation process in a smart environment. A representation model is required to answer questions such as what are the possible activities of the agent? Can the agent be targeted by sensors? Where is the agent now? What is the agent doing now?

Activities/Events Any changes in a smart environment are represented in the form of an event or an activity. Questions such as when an event has occurred, or why such event was recognized, can be answered by representing activities in terms of their preconditions.

Objects Physical objects are also directly or indirectly the target of the observation process in order to recognize activities in a smart environment. We represent objects to answer questions about their state (being in a specific situation), locations, or the events or activities in which they are involved.

Network set-up In order to set-up a smart environment a sensor network deployment related to the observation process, is indispensable. A network representation model is used to answer any question regarding the hardware and software configuration of a network, its components and their locations.

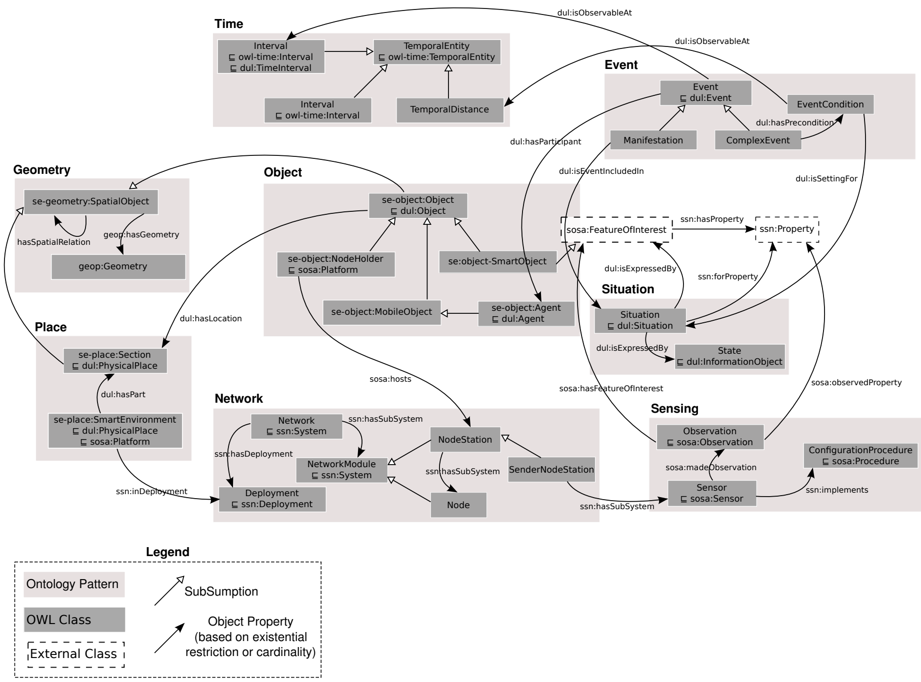

Fig. 1. SmartEnv Ontology is composed of 8 ontology patterns representing different aspects of a smart environment.

Spatial aspect Any physical entity such as objects, agents, and places in a smart environment has a geometrical aspect based on which their spatial relations with the environment can be represented.

Temporal aspect Similar to spatial aspects, the temporal aspects are the main basis of an observation process. A temporal representation model is used to answer questions such as when the occurrence of an activity is realized. It also allows us to define activities based on the temporal relations with their preconditions.

The aforementioned aspects have been modeled in the form of 8 ontology patterns shown in Figure 1. In the following subsections, we briefly introduce each pattern whose representational details can be found in [12].

2.1 Time Pattern

The Time pattern[6] represents any temporal entities that we may use to represent things in a smart environment. In order to represent the temporal aspect of such environments, this pattern has been designed as an extension of the OWL-Time ontology, a W3C recommendation for describing temporal concepts [1].

[6] https://w3id.org/smartenvironment/patterns/time.owl

The OWL-Time ontology provides precise representation for temporal entities in the form of either time instant or temporal duration. In the context of smart environments, we, however, require more specific temporal representation that allows us to also represent relative temporal distance (for example, between an event and its preconditions). For this, we have extended the OWL-Time ontology and introduce it as our **Time** ontology pattern. In this pattern, we define three types of temporal entities representing time instants, time intervals and temporal distances.

2.2 Geometry Pattern

Apart from the temporal aspect, in a sensorized environment, specifically when there are mobile agents such as robots, the representational model needs to also cover the spatial aspects of entities including the topology of objects, rooms, etc. For this, we have designed a pattern called **Geometry**[7] relying on the upper level spatial-related ontology GeoSPARQL [10] and the Open Time and Space Core Vocabularies [1]. The OGC GeoSPARQL standard together with the Open Time and Space Core Vocabulary Specification (which provides qualitative directional relations) define an adequate vocabulary for representing geospatial data enabling qualitative spatial reasoning based on geometrical computations.

2.3 Situation Pattern

A "situation" illustrates a specific *state* of a "feature of interest" (e.g., the temperature of the living room is *warm*)[8]. By feature of interest we refer the concept defined in the SSN ontology as an object which is the interest of the observation process. Although states are usually time dependent, we decided to keep the representation of a situation as abstract as possible for the sake of generality. The concept of situation can be augmented with the concept of time in other patterns such as event-related patterns which are associated with temporal properties.

2.4 Sensing Pattern

A sensing process is simply defined as the process of monitoring a specific property of a feature of interest using a sensing device. In order to represent such concept, we have designed the pattern **Sensing**[9] which is highly relying on the SSN ontology allowing us to model establishment of a sensing process.

2.5 Place Pattern

The meaning of a place in the context of smart environments is twofold. First, by a place we mean the entire smart environment which holds the deployment

7 https://w3id.org/smartenvironment/patterns/geometry.owl
8 https://w3id.org/smartenvironment/patterns/situation.owl
9 https://w3id.org/smartenvironment/patterns/sensing.owl

of a sensor network and might also be composed of several sections. The second meaning of a place refers to each section of the main place with a specific identity that can be as such seen as a location for different objects. Given this preliminary definition, the pattern **Place**[10] defines a place as a specialization of the class `dul:PhysicalPlace`.

2.6 Network Pattern

A network in a smart environment is defined as a system containing different types of devices such as nodes and node stations. By node, we mean a communication module that indicates either a sending or a receiving data module in a network. It is worth mentioning that the current design of the Network Pattern only supports the request/response communication paradigm.

Each node depending on its type can be a part of a node station representing another type of device that contributes in establishing a network. Each node station contains a node along with other things including a sensor, power supplies, batteries etc.

The whole process of a network set-up regardless of its exact technical details is represented by a non-physical concept called deployment. The pattern **Network**[11] unifies the representation of environment automation installations that can be found in different systems.

2.7 Object Pattern

The pattern **Object**[12] allows us to define objects based on their important features or abilities in the context of smart environments. The class `dul:PhysicalObject` provides a suitable representational basis for the objects' taxonomy, which we have categorized into two types of smart objects and node holders. By smart object we refer to those objects that are the interest of an observation process (i.e, feature of interest). Due to the usual difficulties of installing sensors in a smart home, it is common to use some other objects (i.e. node holders) to host sensors. This separation provided by this pattern is specifically useful for other computational modules such as a configuration planner one of whose tasks is checking the status/functionality of sensors by sending a robot to their locations.

Each smart object (or a feature of interest) has at least a property to be observed. Another categorization of smart objects that has been considered in the object pattern, is about their mobility. An objects is considered as mobile only if its location as one of its properties, can change. In order to also be able to reflect the spatial relations between objects (e.g., the "fridge is connected to the cupboard"), or between an object and a place (e.g., "the bed is located at the left side of the bedroom"), it is required to define objects in a smart environment also as a `se-geometry:SpatialObject` defined in the pattern **Geometry**.

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[10] https://w3id.org/smartenvironment/patterns/place.owl

[11] https://w3id.org/smartenvironment/patterns/network.owl

[12] https://w3id.org/smartenvironment/patterns/object.owl

2.8 Event Pattern

The pattern **Event**[13] is an extension of the representation of events in DUL. In this extension we have defined two different types of events including a manifestation and complex event. By manifestation, we refer to those events that can be directly captured from sensor data and represent the occurrence of a smart home situation through a sensing process. However, the latter event type, as its name indicates, represents more complicated events whose occurrence depends on several preconditions [11]. Each precondition as such represents a specific situation assumed to be observed within an interval with a specific temporal distance to the event's occurrence time. Furthermore, the pattern **Time** which is per se based on the OWL-Time ontology, can provide the required basis to represent the temporal properties of the smart environment to capture changes in the form of events or activities.

3 Semantic Interoperability in E-care@home

As an application of the SmartEnv ontology we can refer to health care monitoring and services, where patients are being monitored in their own living environment. The E-care@home project[14] is aiming at providing an IoT-based healthcare system which is composed of various types of sensors continuously monitoring both environmental and medical features related to an elderly person[13]. The elderly user of the system is assumed to have specific needs and potential medical conditions, but is still living at home.

One of the challenges in E-care@home is to achieve semantic interoperability that allows the monitoring system to combine sensor data with background information about the patient in order to provide different services for the patient. These services include recognizing the current situation that the patient is in, the cause of some events, and the best action for the system to take next. The background information can be health reports created by the patient or maybe the patients informal caregivers that are stored in the personal health record (PHR) system or notes from the home care service, primary health care center or hospital that are stored in the electronic health record (EHR) systems. For this to be achieved, the heterogeneity of the services, devices and communication technologies is a major challenge for expanding generic IoT technologies to efficient ICT-supported services for elderly. For instance, the ecarehome system is expected to inform the care giver of the elderly user when it realizes that his/her heart rate has suddenly increased without any reason such as exercising. As another feature of interoperability, the system allows to define high heart rate based on both the health profile of the user (gender, age, health records, etc) and also the current state of the user (i.e., if he/she is resting or actively exercising, etc.).

[13] https://w3id.org/smartenvironment/patterns/event.owl
[14] http://ecareathome.se

4 Extension of SmartEnv

The current version of SmartEnv allows us to represent the context in terms of environmental settings. To achieve semantic interoperability, SmartEnv needs to be extended and linked to other ontologies including those that represent health profile of elderly users (e.g., PHR/EHR[15]) or general medical knowledge e.g., SNOMED CT[16].

For instance, the reasoner applied on SmartEnv knowledge needs to also know about the disease, their causes and their symptoms. Such information has been already modeled in SNOMED CT ontology, however, not necessarily with properties compatible with what defined in patterns of SmartEnv. The question is if we can interlink the SNOMED CT ontology to SmartEnv by redefining a disease as an event (sub class of the ComplexEvent class in SmartEnv), whose preconditions are the same as its symptoms (For further information see Event pattern [12], section 4.8).

Furthermore, many symptoms of diseases are conditional and might change based on the user's health profile (i.e., PHR/EHR). Apart from the user's profile, the threshold values indicating normal or abnormal state of specific physiological parameters such as heart rate or blood pressure also depends on the type of sensors used in the measurement process. In other words, the representation of the sensing pattern in the SmartEnv ontology (see sensing pattern [12], section 4.4) which assigns a threshold values for class Sensor might change and be linked to the ontology representing PHR/EHR information. More specifically, since in health record of the user, the range of normal and abnormal values (or thresholds) for different physiological parameters are mentioned based on specific types of sensors, the sensing pattern in the SmartEnv ontology which includes representation of sensors, and observation process may also be updated and linked to other ontologies [14] designed to represent personal health records of the user.

In summary, the next step towards achieving semantic interoperability in health care includes integration of patterns in SmartEnv with other ontologies in the health-care domain.

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[15] http://sele.inf.um.es/CEM2Archetypes/
[16] http://purl.bioontology.org/ontology/SNOMEDCT

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