Multiple Ontology Binding in a Smart Building Environment

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Abstract. This paper presents the WiseNET ontology for a holistic smart building that re-purposes and integrates static and dynamic information about different domains composing the built context. This ontology binds to a set of elements (vocabulary) from various ontologies by using semantic rules and linked data techniques. The main advantage of the WiseNET system is to produce extra services to building users and to ease the tasks of building managers.

Keywords: building information model, smart cameras, semantic fusion, interoperability

The creation of a semantic based system that combines multiple ontologies that capture building data is a complex task [2]. Moreover, with the development of the internet of things (IoT), building data has become more dynamic and complex to capture and merge.

For example, building data can be enhanced with event information, sensor information and environment information. Event information is related to data concerning the different events that may occur in a built environment such as their location, the time they occurred, the agents involved, the relation to other events and their consequences. Sensor information describe the different sensing devices deployed in the built environment, the process implemented on them and their detections. Environment information details the building structure, its topology and the different elements contained in a space.

The amalgamation of those elements is required for a complete monitoring of the building activity. To deal with this goal, this paper present an ongoing research called WiseNET (Wise NETwork) [5]. WiseNET is a semantic based system which combines the different information obtained by a sensor network in a built environment about dynamic events. From this data collection, this system is able to deduce the triggering of actions/events in real-time. In a few words, the WiseNET system understands the static building information as well as perceives the dynamic/evolving building data, *i.e.,* is a context-aware system.

The central part of a semantic based system such as WiseNET, is its ontology (the WiseNET ontology) [5]. This OWL-2 ontology provides a vocabulary for integrating, re-purposing and analyzing information about different domains composing the built context.

All the different data-sources are integrated by using semantic rules and linked data techniques such as Uniform Resource Identifiers(URIs) and Resource Description Framework (RDF). Some advantages of using linked data for integration are, firstly the acquisition of extra information from the environment (e.g., the dimensions of a door/wall and the material of the different building elements) directly from the `ifcowl` (TBox + ABox); secondly, it allows the use of small portions of the different ontology models. Consequently, reducing the size of the WiseNET ontology, which facilitates its maintenance and improves its reasoning speed.

Figure 1 shows the primary classes and properties of the WiseNET ontology. The external ontologies were chosen because they cover most of the required concepts of the different domains, particularly:

- The **`DUL`** ontology - provides a set of concepts used for interoperability between different ontologies [3]. This ontology gives the necessary properties to combine spatial information with different types of data.
- The **`event`** ontology - deals with the notion of events and their different properties such as location, time, agents, factors and products [8]. This ontology provides most of the vocabulary required for describing activities and events that may occur in the built environment.
- The **`ifcowl`** ontology - is a semantic representation of the Industry Foundation Classes (IFC) schema, which is a standard for representing building and construction data [6]. This ontology supplies most of the environment concepts required such as the structure of the building, its topology and the different elements contained in a space. The IFC2x3 version was used because it corresponds to the version of the data.
- The **`person`** ontology - provides a minimum set of classes and properties for describing a natural person [7].
- The **`ssn`** ontology - provides a terminology to describe sensors, observations, sensing processes, measurement capabilities and related concepts [1].
- The **`time`** ontology - supplies concepts for describing the temporal properties of resources [4]. This ontology provides all the required concepts about instants, intervals, their duration and their topological relations.

Figure 2 presents an illustration of how the ontology modules are integrated, focusing on **`Detection`** and **`PersonInSpace`** events. A **`Detection`** is a type of event that occurs in an specific point in time/space. A **`PersonInSpace`** event is a container of **`Detections`** relating a specific person with a specific space during a period of time. A **`Detection`** instance and its semantic graph is created each time a smart camera detects a person. More details on smart cameras can be found in [9].

The WiseNET system makes it possible to smart cameras to express in semantic words what they observe. The knowledge sent by the smart cameras is inserted in the ontology, which then uses it for the deduction of events and actions.

This solution may overcome many computer vision problem such as:

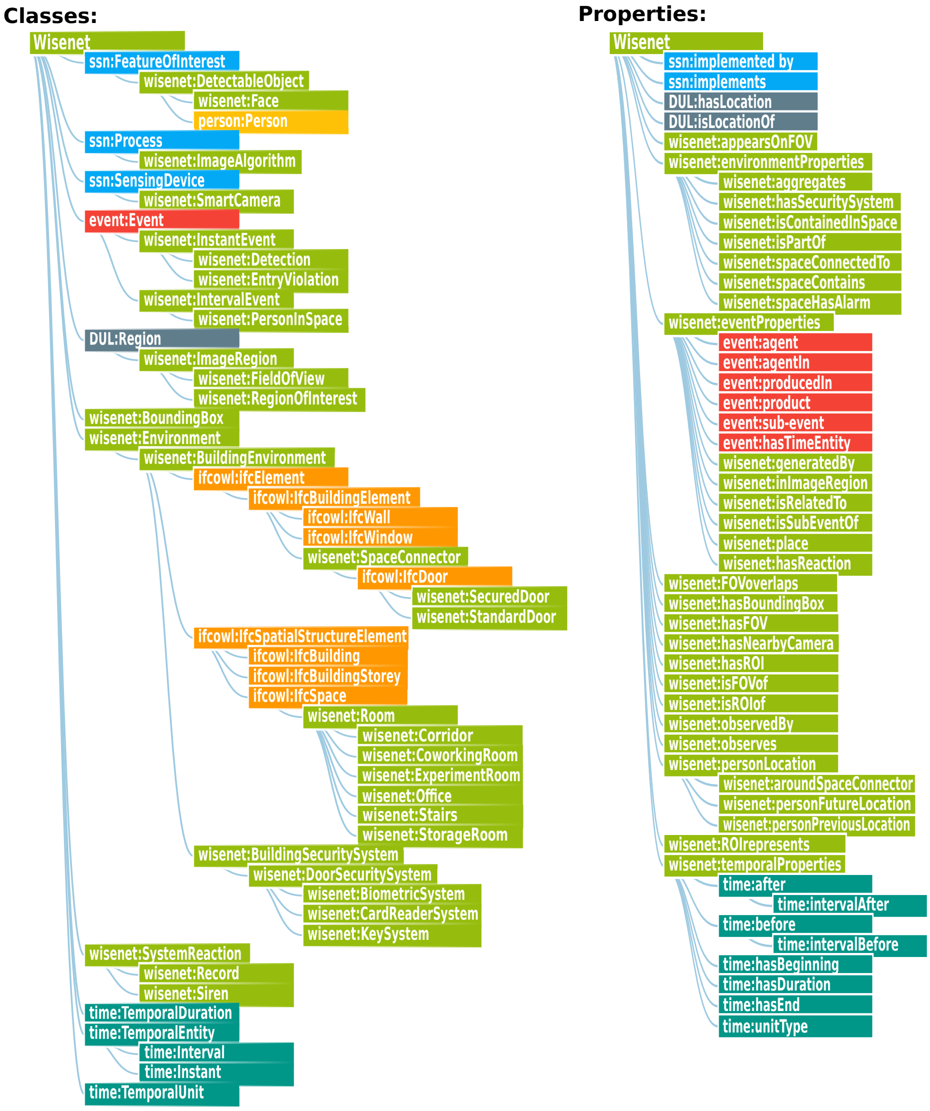

Fig. 1. Primary classes and properties of the WiseNET ontology. The WiseNET ontology reuses resources from many different ontologies such as `DUL`, `event`, `ifcowl`, `person`, `ssn` and `time`. The namespaces and a brief description of the external ontologies are listed in Table 1.

Table 1. List of prefixes and namespaces used in WiseNET ontology and in this document

Prefix	Namespaces	Description
DUL	http://www.ontologydesignpatterns.org/ont/dul/DUL.owl#	DOLCE+DnS ultralite ontology
event	http://purl.org/NET/c4dm/event.owl#	The event ontology
ifcowl	http://ifcowl.openbimstandards.org/IFC2X3_TC1#	The IFC2X3 ontology
owl	http://www.w3.org/2002/07/owl#	The OWL 2 schema vocabulary
person	http://www.w3.org/ns/person#	ISA Person core vocabulary
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#	The RDF concepts vocabulary
rdfs	http://www.w3.org/2000/01/rdf-schema#	The RDF schema vocabulary
ssn	http://purl.oclc.org/NET/ssnx/ssn#	Semantic sensor network ontology
time	http://www.w3.org/2006/time#	OWL-Time ontology
wisenet	http://wisenet.checksem.fr#	The WiseNET ontology

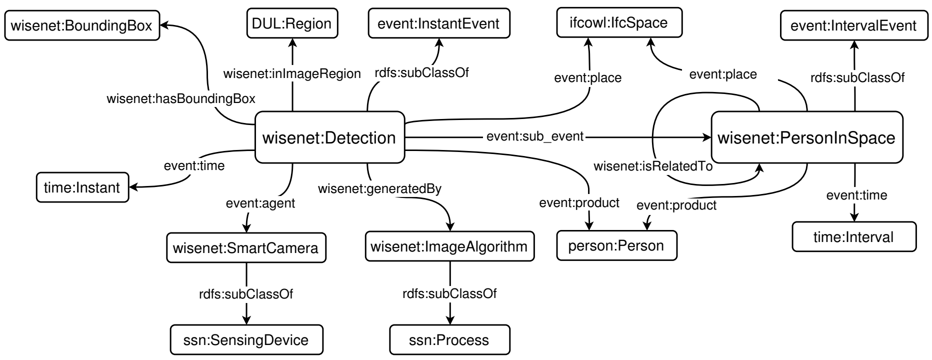

Fig. 2. Semantic network of *Detection* and *PersonInSpace* events, showing the integration of the different ontology modules.

- Missed detections: - this occurs when the system do not detects (misses) pertinent information. The WiseNET system could overcome this problem by using reasoning to advise a smart camera to focus its detection resources in certain door because a person will appear there. This is achieved by predicting the future position of a person using a rule stating that ”the future location of a person detected around a door is the space connected to the current space”.
- False detections - this occurs when the system detects false pertinent information. The WiseNET system overcomes this problem by using the knowledge that a person (normally) does not suddenly appears/disappears, therefore if a person is detected for a very small period of time, then it is a false detection. The knowledge of the image regions (like floor and ceiling) and general people characteristics (like maximum/minimum height) could also be used to notice false detections, for example, ”a person cannot be detected in the ceiling of a room”, or ”a person cannot measure 3 meters”. Also, other rules could be considered such as ”the first detection of a person has to be around a door, if not this is a false detection (or an intruder that entered by the window)”.
- Occlusions - this occurs when pertinent information is outside (or hidden to) the field of view (FOV) of a camera. This is achieved by using contextual information to determine if the person is still in the space.

The system is also the kernel of future frameworks offering smart services, such as:

- People tracking - automatically monitor the people while protecting their privacy by not sending nor saving any image just extracting the knowledge from them.
- People counting - autonomously control the number of people in each space and trigger an alarm if the limitation is (almost) exceeded.
- People guidance - automatically control if a person reached took the correct path or if it's final destination was reached.
- Smart light control system - system that reacts to the human presence not to its movement as most of the systems nowadays.
- Building maintenance - autonomously schedule the maintenance procedures for the building elements (e.g., doors, carpets and windows) according to their usage.

More information of the system as well as more use cases can be found at the website `http://wisenet.checksem.fr`.

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