DomoML-env: an ontology for Human Home Interaction

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Abstract. Household appliances have fast changed in the last decades and achieved an important role in the ordinary home daily activity, e.g. in assisting people during cooking, phone calls, house monitoring, etc. Pervasiveness and interoperability are interesting aspects related to domestic devices. The semantic web is here considered to make an infrastructural support for resource interoperability by providing a domestic environment ontology, called DomoML-env, for human home interactions aiming to connect household appliances each other, to exchange their services and information, and to overcome or extend their individual capabilities. The paper focuses on the development of an extensible ontology in the home automation field, open to the integration of other more specific ontologies.

1 Introduction

Human lifestyle has been changing in the last thirty years. Household appliances had achieved an important role in the ordinary daily activity assisting people during, cooking, phone calls, house supervising, etc. Furthermore, the miniaturization phenomenon of the electronic equipment, market price reduction and additional performance of household appliances encouraged a rush to buying them. People that have bought “tons” of electronic household appliances have a question: “Can these household appliances interact each other giving me an easy way to manage and get some benefit from them?” Unfortunately there is no universal solution able to exchange information and connect household appliances. The communication between them is currently possible for devices built from the same constructor, usually through a bus technology. Many industries have seen a potential new wider market thinking at a new generation of household appliances, able to connect each

other, exchange services and information and overcome or extend their individual capabilities.

On this trend, the idea of making a universal language, able to unify the needs and understanding of the domestic world is pursued in a project called DomoML [1]. And the semantic web is here considered to make an infrastructural support for resource interoperability and integration.

DomoML is a suite of XML based languages composed of three parts which cover environmental elements (DomoML-env) such as household appliances, walls, ceiling, doors, etc.; the universal understanding of any function that an element can have (DomoML-fun); the universal understanding of the communication message between elements (DomoML-com).

This paper focuses on the DomoML-env part describing the experience carried out at SUPSI-DTI and leading to the creation of an ontology about home automation, and its formalization in OWL. In addition, working within Marchiori's Perpception axis context of making semantic web easy [2], some simple real scenarios have been tested in a software prototype.

A number of relevant works in the field of device classification, pervasive computing, and home automation have been considered as starting points. They are here only mentioned in order to better understand the development context of the described work. For further details the specific references are suggested.

A previous home appliances classification done by EHS - European Home System [3] concerns mainly white and brown goods present in a domestic environment. The resulting EHS taxonomy is composed of four major classes including:

- *Meter reading*, which groups all measurement tools
- *HK-House Keeping*, which groups all household appliances and systems such as heating, air conditioning, security, etc
- *Audio and Video*, which groups all multimedia appliances
- *Telecommunication*, which groups all tools able to establish a communication.

Starting from this existing classification of home appliances, a taxonomy of all possible elements/objects present in a domestic environment has been analyzed considering not only devices.

A previous work with relevant objectives about pervasive computing is the SOUPA Project [4]. In this work a Standard Ontology for Ubiquitous and Pervasive Applications (SOUPA) is defined and expressed using the Web Ontology Language (OWL). It includes modular component vocabularies to represent intelligent agents with associated beliefs, desires, and intentions, time, space, events, user profiles, actions, and policies for security and privacy.

Another work about home automation is NICHE (Natural Interaction in Computerized Home Environment) [5], a project started by the Domotics Lab at ISTI-CNR. A relevant aspect of NICHE investigation concerns the ability to capture the unbounded variety of home environments in an incremental way, i.e. in their dynamically evolving aspects. Ideally, the user should be able to deal with new

devices, automatically discovered and integrated in the home system, and interact through the implicit context each specific device carries with itself. For example, in using a TV we would like to be able to use concepts such as “film”, “actor”, “talk show” to take full advantage of next generation distributed smart services. To date the use of a semantic layer in the domain of home networked devices mainly concerns the specification of executed commands, the categorisation of available devices and the mapping between different home protocols. From this point of view the envisioned DomoML suite not only deals with the interoperability issues, but captures all relevant aspects of the environment and agents that modify it. In particular, in the NICHE architecture, DomoML represents the glue among the integration middleware based on OSGi Platform (see also [6]) and the communication middleware on which autonomous agents execute advanced services.

2 The DomoML-env Ontology

Within DomoML, DomoML-env is a vocabulary through which is possible to define physical resources of a domestic environment. Resources are described through a standardized mark-up language based on RDF/XML, which any appliance constructor (or integrator) can use to describe and represent its own products. The adhesion to the DomoML-env will guarantee to different constructors that their appliances will be able not only to communicate with other DomoML-env compliant devices, but also to share semantics mainly about their functionalities, and interoperate on more complex integrated operations. More intelligent complex or macro behaviours may hence emerge from the composition of individual micro behaviours, contributing to the overall home-system behaviour.

2.1 Classification

The DomoML-env taxonomy has been elaborated on the basis of an analytical revision of the EHS taxonomy. The new classification has two main objectives: 1) to strengthen the EHS taxonomy including also stationary elements as wall, floor, table etc.; 2) to break up domestic environment elements into elementary components, e.g. a radio can be fragmented into simple elements such as on/off switcher, tuning switcher, balance switcher, volume switcher, speakers, etc.

This new type of classification allows for an easier element aggregation and greater flexibility of the whole system, making the environment open to the integration of new devices or building objects and increasing their potential coordinated interactions.

A number of super-classes have been abstracted at a higher level in order to encapsulate functionally similar components (Fig. 1). These classes include:

- *Building-Equipment*, which groups all house appliances
- *Component*, which groups all simple elements as switches, valves, sensors, etc
- *Core-Foundation*, which groups all technical or basic elements that a *Component* needs

- *Building-Environment*, which groups all the macro infrastructural components of an house as kitchen, dining room, etc
- *Location*, which defines the location of each element or object within the domestic environment, allowing establishing spatial relationships.

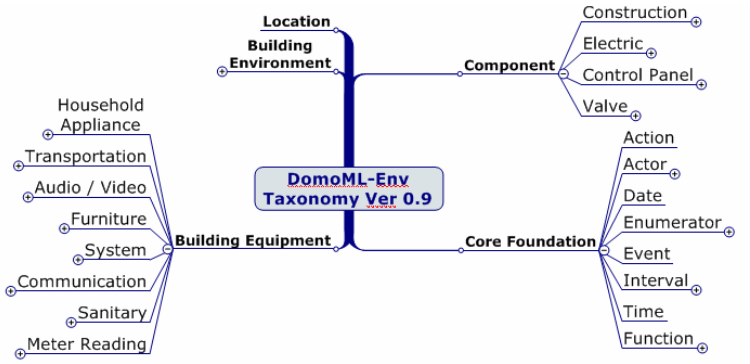

Fig. 1. Main DomoML-env taxonomy elements

The super-classes have been branched in order to detail the classified domestic elements. An excerpt of a sub branch for the Household appliances is presented in Fig. 2 detailing in particular the brown and white goods.

It is worth noting that some similarities with EHS exist, such as a correspondence of the DomoML-env *Building-Equipment* to the EHS' *House-keeping*.

2.2 OWL formalization

On the basis of the taxonomy, an ontology has been then formalized in OWL in order to represent all the home elements in XML/RDF format, i.e. household appliances, furniture, audio/video, communication systems, etc., and some general relationships among the classes. The expressive power of XML/RDF has been used to formally describe elements of the domestic environment and some of their accessible functionalities. For example, a simple midi player instance can be represented as:

```
<rdf:RDF
  xmlns="http://www.supsi.ch/owl/DomoML/0.9/DomoML-env.owl#"
  xmlns:domoML-fun="http://www.supsi.ch/.../0.9/DomoML-fun.owl#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
  <MIDICDPlayer rdf:id="SonyH450" SerialNumber="98761155"
                ModelNumber="450" ModelName="Sony H450 MIDI Player">
    <hasFunctionVolume
                  rdf:resource="domoML-fun:Volume"  rdf:ID="volume">
                <volumeState>0.5</volumeState>
    </hasFunctionVolume>
  </MIDICDPlayer>
</rdf:RDF>
```

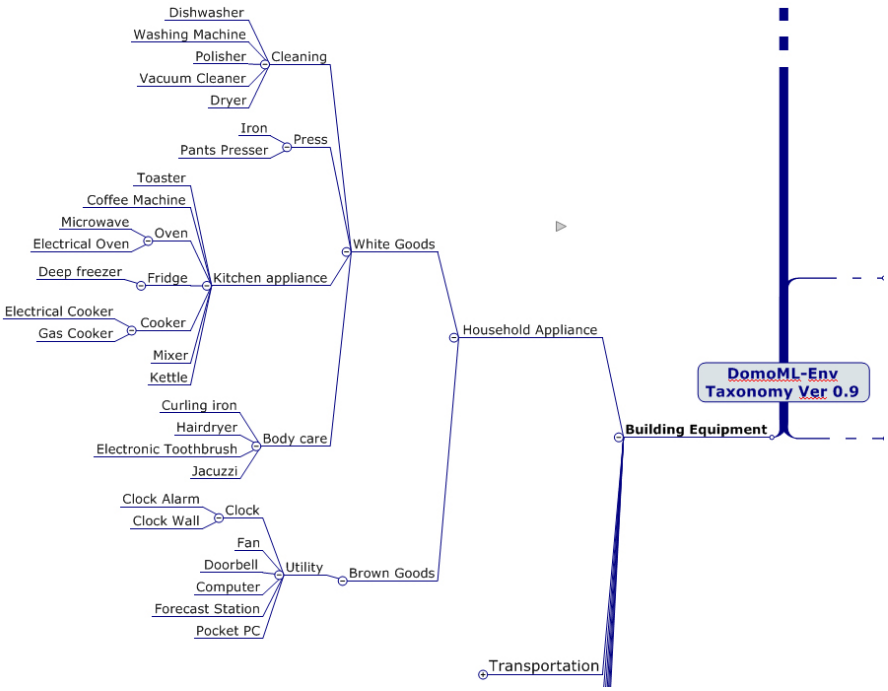

Fig. 2. A DomoML-env taxonomy excerpt detailing the household appliances

The DomoML-env classification has been formalized in a set of 200 OWL classes, reflecting the taxonomy super-classes and sub classes hierarchy. The resulting ontology, on the basis of OWL syntactic mechanisms, allows a very flexible expressive power for describing domestic resources in RDF. Thus, a disaggregating component description of devices permits a finer depiction grain, enhancing the aggregation and flexibility of the whole system, towards an open interoperability integration of new devices or building objects.

2.3 Ontology rationales, management and evolution

The DomoML-env ontology so far defined is an initial step of defining a shared ontology for an open and dynamic environment. Due the nature of the home environment and to the involvement of different players with commercial aims, a shareable ontology should arise from a common understanding of a larger community. This can be technically obtained thanks to the OWL modular mechanism of external ontology import and class/property equivalence. A similar approach is considered also in the SOUPA work [4] where a shared ontology, which combines many useful vocabularies from different consensus, is defined for supporting pervasive computing applications.

Within our context, DomoML-env has been formalized in the form of OWL ontology in order to guarantee the interoperability of domestic resources through semantics sharing. This ontology, although in a preliminary version, aims to be a first generic reference formalization, available to be shared among business players, i.e. companies and/or institutions. In addition, the basic ontology is open to extensions which can better detail, specify, and eventually specialize particular resources or devices according to specific builder constraints. The owl:import and rdf:subClassOf are some of the OWL mechanism which allows it.

Thanks to the DomoML-env ontology, a number of resources, ranging from electrical devices to furniture, can be described with the help of metadata and represented in RDF. This contributes to the generation of a domestic semantic web in an a open and extensible way, on which further elaboration can be done, such as making inferences, but above all establishing useful interactions. The device interoperability so obtained is potentially open to any sort of helpful interactivity which could be established by composition of individual ones. Ambient intelligent scenarios are typical examples of this constructive composition, where sensor/actuator input and output are connected.

In order to obtain a soft integration between the device operational level and its application level, a DomoML wrapper is considered at the interface level. Devices are hence seen as black boxes where necessary functionalities are exposed in term of objectProperties described in the RDF resource instances. For example, the possibility of controlling oven temperature of an electrical cooker is simply represented in an RDF instance through the addition of the following owl:objectProperty relating the cooker to an oven temperature selector:

```
<ElectricalCooker rdf:ID= "ELC5960">
  <hasOvenTemperatureSelector
            rdf:ID="ovenTemperatureSelector">.
```

This representation, more generally, allows specific component properties to be exposed and elsewhere exploited for control, interoperability and composition.

The current ontology is to be augmented by the definition of generic rules working on the resources and their properties (data and relations). Inferences of these rules can establish useful complex behaviors of the whole domestic system (e.g. safety/security monitoring system).

Firstly, in the existing prototype, we have analyzed and experimented with the level of resource (device) representation, and a simple direct mechanism of querying the semantic web has been established. Next step will be to study and try to use the formal standard languages, which, although not yet standardized, may provide a more sophisticated inference mechanism. This approach will have to consider, for instance, appropriate languages for rules and inference like W3C's RuleML [7], SWRL[8], or, as it has been previously experimented in a NICHE prototype, like metalog [9].

3 Prototype

The resulting language, called DomoML-env, has been used in an experimental prototype (completed by the other DomoML components, i.e. the functional language DomoML-fun, and the communication language DomoML-com). Some scenarios

have initially been considered for simulating situations of device interoperability in order to put in place a more complex behavior. An example of such a scenario is when at a phone call a cooker must be lowered down and the midi-player volume reduced or switched off.

The initial prototype architecture implementation is a simplification of the one previously described in [1] and it is composed of two elements: the server, called "System Agent", and the clients, called "Devices".

The server is primarily in charge of registering and coordinating the devices (household appliances) which are or are going to be installed into the domestic environment, according to their RDF descriptions. Its second important job is to dispatch messages coming from devices. The clients represent individual devices, i.e. household appliances installed into the environment. Both server and clients support the DomoML interface (middleware) which carries on the interaction between environment elements.

4 Conclusions

Working within a perception context of making semantic web tangible, this research has investigated the possibility of creating a universal language, DomoML, associated to an ontology, DomoML-env, through which global communication between elements/objects present in a domestic environment is made possible. These elements, ranging from devices to structural objects, eventually include the end user, and therefore allow DomoML-env to be considered a first step towards human-home interaction for ambient intelligence based on the semantic web. Finally, the development of a prototype allows the application of semantic web technology to home automation to be tested. Benefits and issues related to it emerged and need a further work of thorough analyses.

References

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