Rapid Prototyping Of Semantic Applications In Smart Spaces With A Visual Rule Language

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Abstract
One of the major limitations of Ambient Intelligent systems today is the lack of semantic models in human behavior and the environment, so that the system can recognize the specific activity being performed by the users and act accordingly. In this context, we address the general problem of knowledge representation in Smart Spaces. In order to monitor and act over human behavior in intelligent environments, we design a sufficiently simple and flexible visual language to be managed by non-expert users, thus facilitating the programming of the environment. The prototype of the visual language serves to represent rules about human behavior to provide the Smart Space with more usability. These rules can be mapped into SPARQL queries and rule subscriptions. In addition, we add support to represent imprecise and fuzzy knowledge. The proposed general-domain language can help managing resource allocation, assisting people with special needs, in remote monitoring and other domains.

Author Keywords
Smart Spaces, Fuzzy Ontology, Rule Visual Language, Interoperability, Human Computer Interaction

ACM Classification Keywords
D.3.1 [Formal Definitions and Theory]: Semantics.; D.1.7 [Programming Techniques]: Visual Programming.; I.2.4

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Programming Smart Spaces

The main goal of ubiquitous Smart Spaces is to work towards an ideal environment where humans and surrounding devices interact effortlessly [10]. The environment would be capable of recognizing and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way [1]. Although context-awareness is key issue in these environments, many applications and devices, per se, do not fully take advantage of context information. Semantic technologies have shown to be successful in areas such as Ambient Intelligence, context representation and reasoning.

Some good examples that let non expert users to take part in the configuration and personalization [6] of a Smart Space and create their own services or applications, through simple rules, are *If This Then That* [1] for online social services or *Twine* [2] for applications based on sensor interaction. Existing frameworks lack underlying semantic capabilities for device interoperability and support for fuzzy rule expressions through linguistic labels.

Our previous work shows different approaches on rapid-development of Smart Spaces applications focusing on Object Oriented programming of rule-based applications and abstracting away semantic web technologies [9]. However, in this approach we focus on users with no programming experience. We focus on designing a semantic visual tool for non-experts to rapidly prototype Smart Space applications by a) providing semantics to enhance the context-awareness, and b) permitting imprecise or vague every-day life expressions.

A visual language for semantic and fuzzy programming of Smart Spaces

Our proposed visual language prototype mockup can be seen in Fig. 1. Nodes represent classes in the underlying application ontology, except for the purple small nodes, which represent literal datatypes. Services (gray nodes) have an associated grounding based on an external application, which serves to act on the environment. Arches represent data and object properties, and their instantiation is used to represent (and query) individuals (i.e., instances).

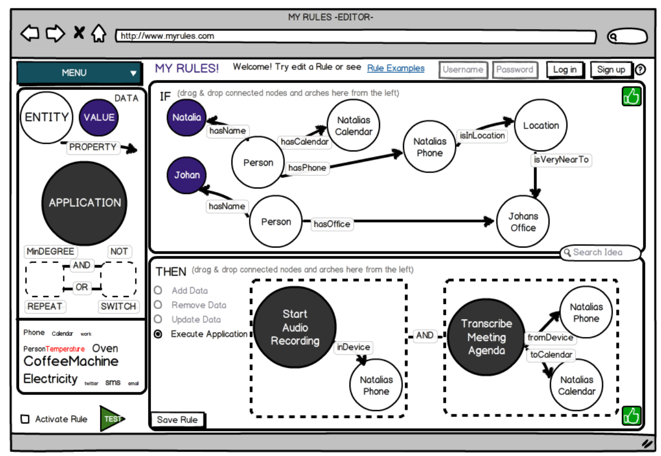

Figure 1: User interface mock-up and example of semantic rule construction [4].

The algorithm that maps a visual rule into a SPARQL query-based subscription in our publish/subscribe architecture, M3 Redland can be found in [4]. IF/THEN

[1] http://ifttt.com
[2] http://supermechanical.com/twine/

(Mamdani) rules can involve all kinds of sensors and they should be able to be tested before activation, as well as shared among users. The pub/sub mechanism allows that every time the knowledge base contains the graph pattern in the rule antecedent, and a service grounding is found for the specified actuators in the consequent, the rule is triggered.

The architecture is based on a hybrid fuzzy-crisp knowledge base [5] composed by standard semantic technologies support (OWL 2, SPARQL, RDF) as well as real-time event notifications through M3 pub/sub architecture. At the same time, the architecture relays on a semantic underlying layer which allows inference as well as fuzzy reasoning through *fuzzyDL* [2]. The integration of *fuzzyDL* provides expressive power in more natural language within a versatile framework for developing Smart Space applications.

The proposed architecture' strategy allows loosening of semantics or efficiency (depending on application needs), avoiding continuous querying for changes or fuzzy discretization-based solutions. This results on more flexible knowledge representation and queries. More details of the hybrid crisp-fuzzy architecture can be seen in [5].

Discussion and Future Work

The proposed framework supposes a step forward towards the integration of semantic and fuzzy representation of knowledge in rule-based systems for end-users with no technical knowledge. Natural language and expressions such as *If Natalia enters the room of his supervisor, start audio-recording the meeting agenda in her phone's calendar*. The aim would be keeping track, for future reference, of the agenda points and brainstorming ideas discussed, on the user's calendar. Semantic Web community has not yet adopted Fuzzy Logic technologies [11], even if the latter supposes a clear advantage on expressing everyday regular language and account for natural imprecision and uncertainty of real life situations. Our proposal aims at bridging this gap and tries to reach non technical users for these technologies to take off and be taken advantage of in real applications outside research. Otherwise, as Prof. J. Kacprzyk said, fuzzy logic theories can remain as our *local heroes*.

Next steps will consist on implementing the visual language and performing usability and performance tests. Future works should aim at unifying the semantic query languages together with fuzzy reasoners such as *fuzzyDL* [2]. Rules could also be extracted automatically by observing the user behavior patterns so that ultimately, the user would not need to give any explicit input or perhaps, correcting suggested mined rules would be enough. For this approach, existing work on detection of activities of daily living [3, 7], e.g. in Smart Homes or for assisting the elderly, could be used. Different data-driven approaches such as HMM [8] are common and successful learning techniques in this area. Furthermore, our ontology-based semantic layer could complement the human behavior models by supporting rule-based adaptation to behavior changes, new sensor input readings and other context-aware situations.

In order to improve the proposed architecture, it would be very useful if W3C standards would integrate fuzzy extensions to allow query federation for also imprecise knowledge. By allowing fuzzy reasoning in the Semantic Web, more usable, flexible, personalized and adaptive Smart Spaces would be achieved.

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