Leveraging ambient applications interactions with their environment to improve services selection relevancy

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Abstract: Semantic web technologies are gaining momentum in the WoT (Web of Things) community for its promising ability to manage the increasing semantic heterogeneity between devices (Semantic Web of Things, SWoT). However, most of the approaches rely on ad-hoc and static knowledge models (ontologies) designed for specific domains and applications. While it is a solution for handling the semantic heterogeneity issue, it offers no perspective in term of ontology evolution over time. We study in this poster several approaches allowing: (1) to handle the semantic heterogeneity issue; (2) to capitalize the knowledge contributions throughout the life of the system allowing it to potentially better assist people in their environment over time. One of the approaches is validated on a real use-case.

Key-words: Semantic web of things (SWoT); Knowledge modelling; Knowledge capitalization, Ambient services selection.

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Introduction

Today, smart devices are widely deployed and work in concert to assist users in several distinct domains (healthcare, smart houses, etc…). This cooperation requires a strong interoperability between devices, firstly achieved by allowing them to communicate. Although work on communication protocols (IoT, Internet of Things) tries to provide a solution to the technological heterogeneity issue, it is still challenging due to the large number of initiatives [1] in this field. Among all the possible solutions, web services based approach (WoT, Web of Things) is now widely accepted [2]. From this hypothesis, we can now focus on the heterogeneity issue but from a semantic standpoint. Indeed, devices produce physical world data now enriched with semantic metadata used to qualify it (SWoT, Semantic Web of Things) and increase the relevancy of the selected ambient services.

In most of the current work, metadata relies on a static and ad-hoc knowledge model (ontology) structuring all the concepts and relationships for a specific domain targeting specific applications (smart homes, building automation, healthcare, etc…).

However, while this approach is a solution for handling the semantic heterogeneity issue, it offers no perspective in term of ontology evolution. Thus, extending the scope of use of the information to multiple applicative domains implies to develop a comprehensive ontology from heterogeneous ontologies which is unlikely to happen in the SWoT context where domains to cover are countless. In addition, most of the existing domain ontologies doesn't follow the semantic web best practices, limiting, de facto, the reusability of their information outside their initial scope [3].

Some projects acknowledged the fact that multiple heterogeneous ontologies management is inevitable in the context of systems targeting a wide range of applicative domains. For example, in the context of ambient intelligent environments (AIEs), ATRACO project [4] authors envision that a comprehensive, agreed and validated ontology is unlikely to happen, and that, more realistically, device manufacturers will independently develop their own ontologies. This project is based on an upper ontology but allows software agents to independently and locally describe and rely on their own ontology. While an ontology alignment engine is developed to cope with the semantic heterogeneity issue at run time, it still offers no perspective for the upper ontology to capitalize the contribution of agents' local ontologies over time.

For example, let's consider an environment containing a recent DVD player embedding a local ontology partially modelling the knowledge about the video formats it is able to play (i.e. MPEG-2). The query "What are the available appliances able to play MPEG-1?" will return no answer. Considering now a newly discovered DVD player embedding a local ontology modelling that MPEG-2 format is backwards-compatible with MPEG-1 format, the previous query will now return the two appliances. By not capitalizing the contribution of this new knowledge, the same query will again return no answer if the second DVD player local ontology is not reachable anymore.

Our contribution relies on a knowledge architecture managing the semantic heterogeneity issue but also permitting to capitalize the knowledge contributions throughout the life of the system. First, we study several approaches and their associated architectures and classify them according to two criteria: (1) their capacity at managing the semantic heterogeneity, (2) their faculty at permitting the knowledge enrichment over time. One of the approaches is then validated on a real use-case.

Use-case description

We consider in this use-case (Figure 1) the possible displacements of an elderly person in her macroscopic environment. 99% of the time, this person is either located at home (yellow circle) or run errands (blue circle). While the person remains inside the cycle (pink cycle), no new device are discovered in her environment and the system knowledge remains stable but potentially incomplete. Then, exceptionally, this person has to visit a friend (green circle). Once in her friend's environment, new devices are discovered contributing at enriching the system knowledge and potentially incrementing the initial incomplete knowledge. Back to the traditional move cycle, the newly added knowledge may leads the system to better assist the person.

Figure 1 : Elderly person displacements scheme

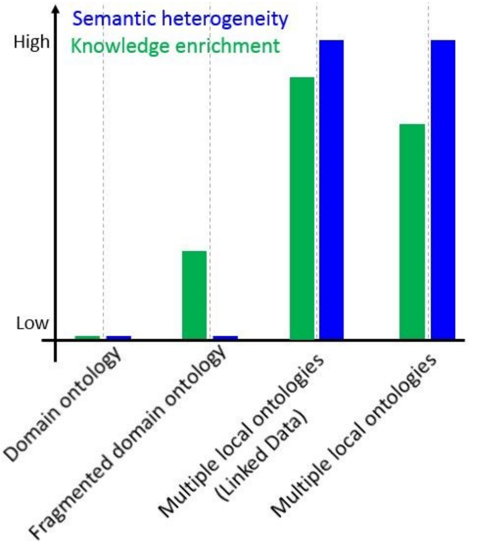

Figure 1 : Knowledge management approaches expected performances

Three Knowledge management approaches

Fragmented domain ontology approach

With this approach, devices semantic metadata bring fragments of a comprehensive domain ontology. The knowledge grows as devices are discovered over time and contains only the necessary knowledge. The knowledge is bounded to the content of the domain ontology the fragments are extracted from, limiting de facto the knowledge enrichment capability but preventing semantic heterogeneous issues.

Multiple local ontologies with linked data approach

Devices semantic metadata are based on their own local ontology. With this approach, concepts are locally defined and can be linked to other concepts described either in other local ontology (owl:sameAs or owl:equivalentClass) or defined "somewhere" on the web (dereferenced URI) [5]. This approach is good at managing the semantic heterogeneity and reducing the alignment process inaccuracies. For that reason, it is the one from which we expect the better results (Figure 2). Additionally, linked data usage can: (1) ensure up to date information (for example, dereferenced URI can point to the manufacturer devices knowledge repository returning the latest device description as an RDF graph) and then (2) can help alleviating the metadata content.

Multiple local ontologies approach

This approach is equivalent to the previously described approach but without the linked data hence relying on the utilization of a fully automated alignment engine inducing inaccuracy that makes the knowledge enrichment less efficient.

Location	Device	Classes	Axioms
Home	Boiler	100	453
Home	Clock	13	69
Home	Computer	24	124
Home	Cooker	48	109
Home	DeepFreezer	48	105
Home	DishWasher	38	110
Home	Fan	24	124
Home	Oven	109	489
Home	Printer	24	124
Shop	CoffeeMaker	24	124
Shop	Computer	13	58
Shop	DeepFreezer	100	454
Shop	Entertainment	11	30
Shop	Fan	2	4
Shop	Fridge	44	73
Shop	Printer	11	49
Friend	**Clock**	24	122
Friend	Computer	2	4
Friend	**Cooker**	88	408
Friend	**DishWasher**	97	444
Friend	Entertainment	24	124
Friend	Fridge	109	502
Friend	Oven	26	67
Friend	WashingMachine	110	490

Table 1 : Each device, through semantic annotations brings a local ontology describing its domain (potentially incomplete).

Experimentations

Dataset selection

To the best of our knowledge, there is currently no dataset available on the web applicable to validate the proposed approaches. Instead, most of the works are relying on a comprehensive ontology at a basis to describe all the knowledge for a given domain. Since ontology engineering is a time consuming task necessitating expertise to ensure knowledge modelling coherency, we have used DogOnt ontology [6] rev 3.2.11 describing 926 concepts and containing 9383 axioms. This ontology is general enough to be used in a wide range of domains. The dataset is then created by fragmenting the ontology into sub-ontologies defining and structuring all the knowledge necessary to fully describe some devices. Then, from each sub-ontology, are generated a set of degraded sub-ontologies (see Table 1) containing a subset of the device complete knowledge. Using this approach has permitted to elaborate a comprehensive electrical appliances dataset used to get reproducible measures by still keeping the control on the fragmentation and degradation rates. From multiple local ontologies approaches standpoint, this experimental dataset assumes that linked data and alignment engine perfectly smooth the semantic heterogeneity appearing when dealing with ontologies independently developed.

Results

Results are exhibited in the Figure 3. After having discovered all devices in the usual environment of the elderly person (1), the system knowledge (blue curve) remains flat as long as the person does not come out of this environment (2). The person visits her friend and new devices are discovered in this new environment (3). The newly added knowledge is made persistent in the system when the person is back to home (4). New knowledge has been added on the clock, the cooker and the dishwasher appliances (Table 1). This leads the system to potentially improve the relevancy of devices to be used in concert and then better assist the elderly person in her everyday life.

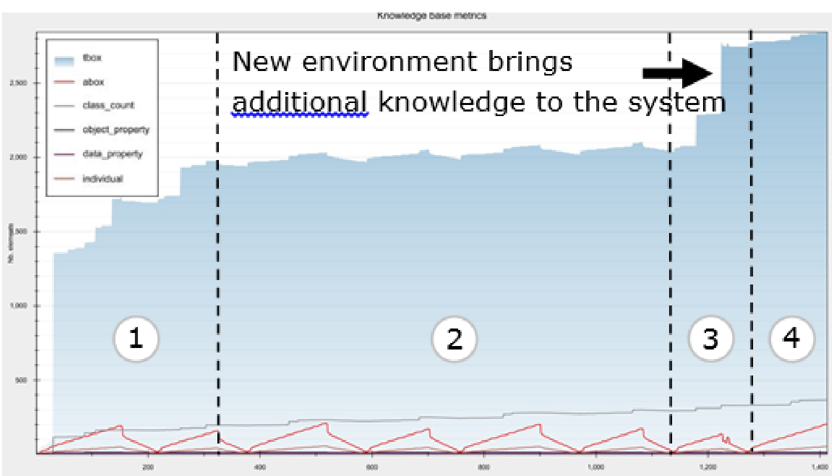

Figure 3 : Use-case execution results

Conclusion and perspectives

In this poster we presented a preliminary assessment and design of a knowledge management approach aimed at handling ambient services semantic heterogeneity and, by capitalizing the knowledge contributions throughout the life of the system, at better assisting people in their environment. However, while the knowledge increases, limitations may occur in space (system memory limitation) and time (query processing time). A tradeoff has to be found in between handling the semantic heterogeneity, the intrinsic system capabilities and the user experience. Also, care will have to be taken on the knowledge description model validity over time.

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