Ontology Powered Knowledge Modeling For A Smart Home

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Abstract

The development and expansion of ontology is highly important in building smart applications such as a smart home. This research seeks to identify and develop an extension framework for personalized smart home ontology that can be used in an intelligent home to reduce and manage the energy consumption. The ontology framework was developed based on a methodology known as Natalya and Deborah Methodology. In the design, the researcher added the home appliances as sub classes, and grouped them based on their functional properties. This approach was not used before in the previous work. With this approach, any kind of home appliances can be semantically defined. In order to validate the proposed framework, the researcher developed a prototype to check the consistency and the correction of a Smart Home Ontology and Semantic Web Rule (SWRL). The ontology was validated through the pellet reasoning engine and Simple Protocol and RDF Query language (SPARQL) query to test and correct any logical mistake in the SWRL rules or in the ontology created.

Key words: Ontology, Smart home, Smart home ontology, Energy saving**.**

i. Introduction

Recent environmental problems like global warming and climate change have made sustainability a very serious concern in the turn of the century. This matter has turned the focus of industries on using eco-friendly products that ingest less, and inexhaustible energy. In this regard, information technology industry is playing an important role in solving environmental and energy problems. The IT industry is using technology for the purpose of greening, which is also known as 'green IT' or 'green computing'. This is divided into two main types, which includes Greening of IT and Greening by IT. Greening of IT aims at reducing energy consumed by IT equipment and plant such as PCs, servers, network equipment, consumer products. This constitutes around two percent of the entire energy depletion and it is equal to the total energy consumption of aerospace engineering. Greening by Information Technology encourages decrease in energy use in areas not related to information around 98 Percent of the whole energy usage [1] [2].

Accordingly, improving energy efficiency can be achieved by reducing the energy consumption in households through IT enabled devices. This concept is also referred to as smart home paradigms, which envision houses as intelligent entities. The smart home concept or paradigm can allow the users to accomplish a wide number of tasks automatically in order to be responsive to user needs and adaptive to the context. This is a mandatory task represented by intelligent energy management that a smart home environment has to support [2].

Many heterogeneous electrical and electronic devices at home work independently to support users in performing everyday tasks. Gradually, more and more intelligence has been introduced in the home environment for the convenience of the users. This will allow the devices to automatically accomplish several tasks at once and enable more effective maintenance and management of energy consumption [2].

In order to facilitate the design of smart home applications, ontology is needed to represent home automation system. Ontology has become a mean to represent the application system that serves specific purposes upon the current knowledge for many years. The main aim for designing the ontology is to make the knowledge easily reusable and shared by the communities and the users of the same domain [3]. The application of Semantic Web technologies such as a knowledge store or ontology is considered in the process. Ontology can be developed using specific ontology languages such as the Recourse Description framework Schema Language (RDF-S). It is considered in the World Wide Web Consortium [4] as a semantic extension of resource description framework (RDF) that provides mechanisms for describing groups of related resources and the relationships between these resources. On the other hand, the Web Ontology Language (OWL) is considered as one of the most important ontology language for the Semantic Web [5]

A considerable body of literature exists on the topic of ontology and the methodologies for developing an ontology-powered knowledge modeling for a smart home. However, this paper addressing the problem of building a personalized home automation system for saving energy consumption for the electrical devices in implicit, explicit or hybrid ways which is not yet available. The rest of the sections attempt to further discuss the research gap and how a paper is conducted in order to fill out the gap.

ii. Related work

For the best energy efficient operation there, storage and retrieval of information is tremendous. The more there is an availability of extra data on the buildings' status, the quicker automation systems can actually, achieve optimum conditions for the residents and the environment [5] [6].

In [5], the authors argued that to achieve the smart automation system, the availability of data and the intelligent storage was inevitable. They suggested to use a specified building information models as a specified source and as well as

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Semantic Web Technologies as a specified store of the data based buildings. Therefore, a transformation of a building information model, gbXML to Web Ontology Language was highly accepted. Indeed, the more information is highly available on the properties of the building related to smart homes, the better the suggested system can act as comfortable and friendly ambience. Moreover, the information's transition of data and information from the model of the building into a specified intelligent information base as foundation of the autonomous automation system is required.

Because energy consumption and production require to be managed effectively in such unique perspective to enable extra efficiency of the energy management. Grassi et al in [6] presented such novel holistic vision in particular for the environments of smart home while offering a specified ontology framework conceived to present the needed knowledge modeling in its regular implementation. The authors focused on two main components of the ontologies which they developed to describe devices along with power consumption/ generation to enable the involved intelligent task management for the consumption of energy optimisation.

In [1], the researcher present an ontology-based reasoning approach for saving energy in a smart home. Their framework shows in fig 3 which they used a mobile phone as a generic sensor which can collect the inhabitant's contextual data. They built an ontology to save the energy consumption in a smart home and identifies a semantic web rules based on two-day scenario for four family members. The drawback was the home personalization issue which cannot distinguish between the individual needs and the sensors response.

iii. Energy Saving Framework for Smart Home

The Ontology Powered Knowledge Modeling of a Smart Home conducted for saving the energy usage in a smart home founded on the ontology concept. Researcher applies a proposed ontology powered modeling scheme to personalize the home automation while saving the overall power consumption. Personalized home automation can be categorized into implicit, explicit, and hybrid personalization.

1. The implicit personalization based on a user's interest, behavior and attitude. The home automation ontology will store the information about a person's interest and routine activities in human understandable and machine executable format.

2. The explicit personalization, a user can manually change the features of an indoor ecosystem with an input that can be fed into the system through a smart phone application.

3. The hybrid personalization is the amalgamation of both implicit and explicit personalization.

The proposed ontology will serve the wide-ranging three-personalization modes that have been defined above. Within the conventional home automation, systems appliances execute based on the stipulated commands. For instance, the bedrooms lights are typically programmed to light up with the darkness outside or with a set clock hour. If a person does not enjoy lights to be turned on atomically in his/her presence at evening time, the home automation system should act automatically based on the linking of the person.

As display in the fig 1, each person has personal preferences that will be presents in ontology as resource description framework (RDF). Moreover, the home appliances information along with their status (on, off) will also be stockpiled inside the ontology. Smart phone application will conduct ping requests to all the appliances to get their status information. Status information along their default behavior, Global Positioning System (GPS) coordinates and personal preferences will populate the ontology.

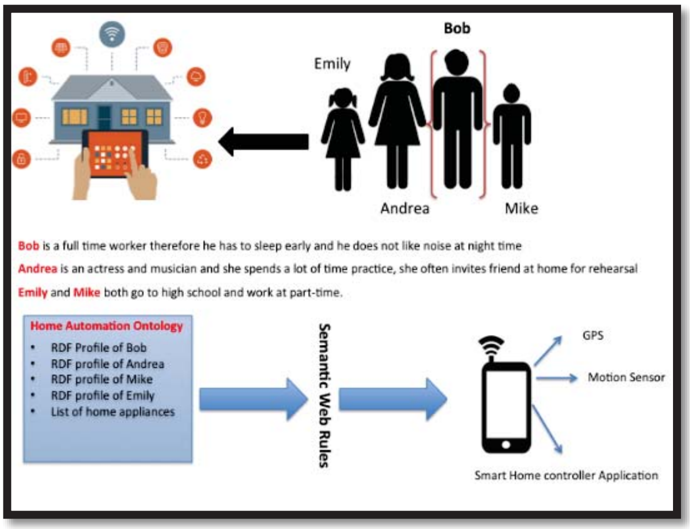

Fig 1: Personalized home automation framework

iv. Smart Home Ontology Development

The researcher follows the Antalya and Deborah approach for the development process. The Smart Home Ontology will be build using a protégé tool; it is a free, open source ontology editor and knowledge-based framework. The Protégé platform supports two main ways of modeling ontologies via the Protégé-Frames and Protégé-OWL editors. Protégé ontologies can be exported into a variety of formats including RDF, RDFS, OWL, and XML Schema [7]. The Smart Home ontology class hierarchy is shown in fig 2. Place and Agent classes are reuse it from purl.org website to promote semantic integration.

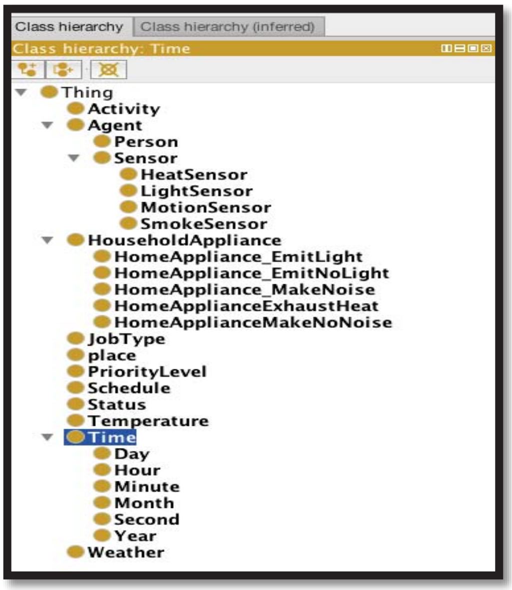

Fig 2: Smart Home class Hierarchy

v. Semantic Web Rules (SWRL)

SWRL are logical piece of code, which are designed to derive some logical decisions [8]. In semantic web, SWRL rules are employed to take intelligence decisions out of data stored in knowledge base (ontology instances) [8] .In smart home ontology, the SWRL that the researcher introduced will facilitate a user to yield new knowledge (implicit, explicit and hybrid) based on the existing implicit knowledge. In smart home ontology all the rules are designed independent (see fig 3), which means they are not dependent on a particular person's profile. Rather, a rule will automatically be triggered when any profile matches with rules properties.

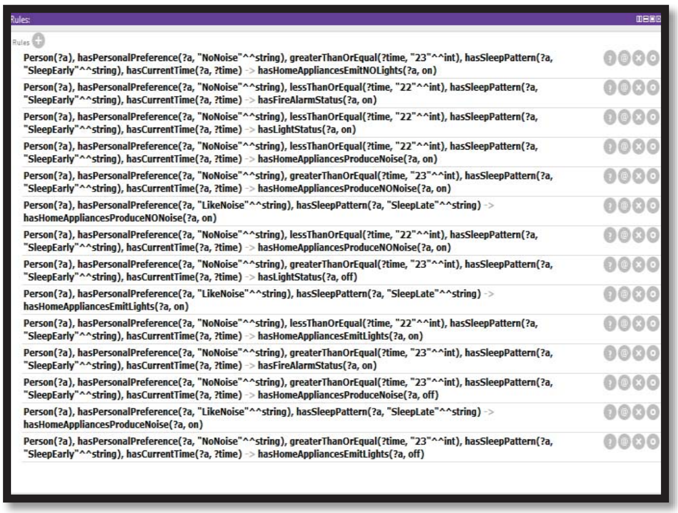

Fig 3: Semantic Web Rules in Smart Home Ontology

Example of the rule: Person (?a),hasPersonalPreference(?a,"NoNoise"^^string), greaterThanOrEqual(?time, "22"^^int), hasSleepPattern(?a, "SleepEarly"^^string), hasCurrentTime(?a, ?time) -> hasHomeAppliancesProduceNoise(?a, off)

Explanation: The above rule can be illustrated as, if a person (could be any, independent of gender) does not like noise and he/she usually sleep early and if the time is greater or equal to 10 PM then shut down all the device that produce noise.

vi. Smart Home Ontology Evaluation through Pellet reasoning engine

The researcher has configured Pellet reasoning engine to evaluate the SWRL rule that have been introduced in smart home ontology. Pellet started as a proof of concept system to help meet the W3C's implementation experience requirements for the Web Ontology Language (OWL) [8]. It has since become a practical and popular tool for working with OWL [8]. Pellet has been the first reasoning engine that supports all of OWL-DL, i.e., the Description Logic (DL) SHOIN (D), and recently, it has been extended to support the new features proposed in the so-called OWL 1.1 effort 1, i.e. the DL SROIQ(D) [8].

- **CASE 1:**

Fig 4 and 5 displays a profile of a person Bob who is an engineer therefore he has to sleep early to get up and go to work early morning. He likes to all the light turned off when the time is 22. Here a person can set any time base on his personal preferences. In smart home environment when the application would be built based on the smart home ontology the time input would come from the smart watch or any sensor that would be synchronized with the home appliances. Fig 4 is the view without inference, when we apply the reasoning engine; it takes the profile information as input and consults the SWRL rules to seek the appropriate one.

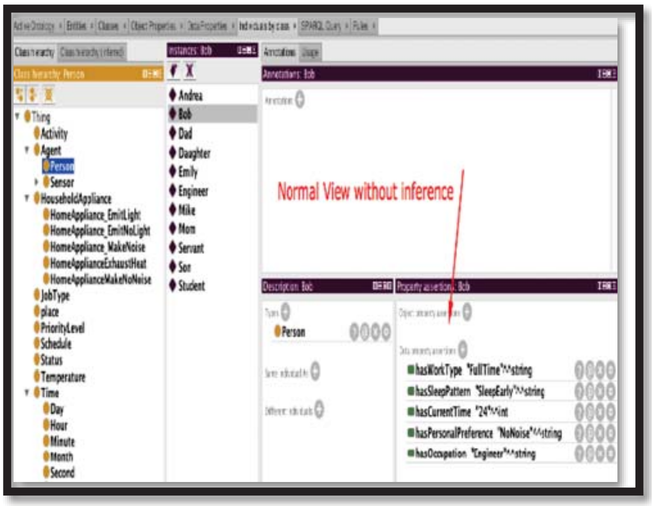

Fig 4:Bob's Profile without inference

In fig 5, you can observe the deduced or inference results, which have been yielded, based on the personal profile. The inferences results argue that all the home appliances those emit lights and produce noise, room blinds and room lights shall be turned off. However, the fire alarm would not off to avoid which is one security requirement in home.

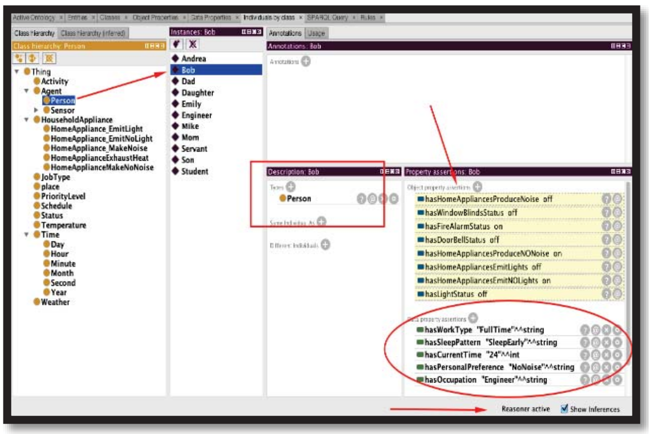

Fig 5: Bob's Profile with inference results produced by the Pellet reasoning engine

- **CASE 2:**

In Case 2, person has four main preferences. The person has occupation actress and she likes to work late nights and does not mind if the lights remain '*ON*' as she does not need to wake up early morning for full-time job. Fig 6 depicts the preferences without inference results. This is noteworthy that the inference engine would not produce any deduced or inference results if there is any logical mistake in the SWRL rules or in the ontology. Hence, we can derive the conclusion that the smart home ontology is working properly with in defined scope. Based on the personal profile the inference engine yields that lights and noise-producing appliances could remain on (see fig 7).

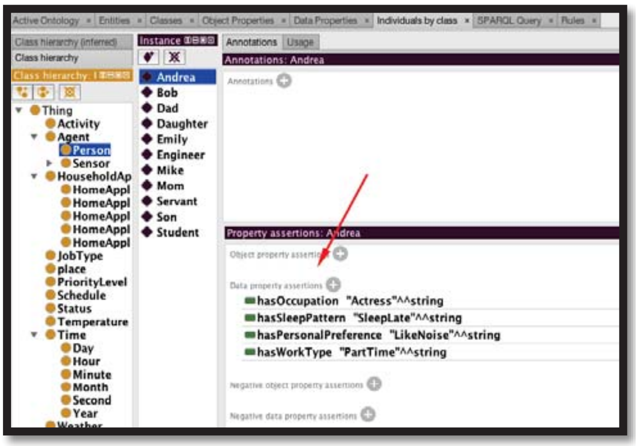

Fig 6: Andrea's Profile without inference results

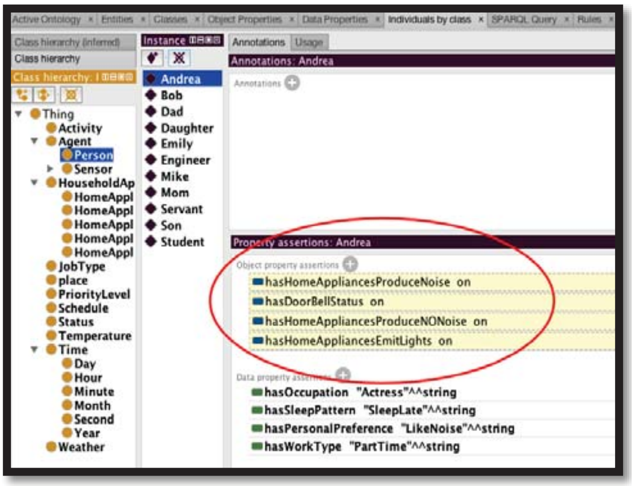

Fig 7: Ontology view after applying the SWRL rules and invoking the reasoning engine

vii. Ontology Evaluation through SPARQL

The authors has adopted SPARQL query based ontology evaluation technique to observe whether all the ontology parameters are working according to the requirements. SPARQL is a query language designed specifically to query RDF databases and ontologies. SPARQL queries are sent from a client to a server known as a SPARQL end point by using the HTTP protocol [10].In the smart home ontology, the researcher has configured the SPARQL tab. The interaction between the client and the endpoint is defined in a machine-friendly protocol that is not intended to be interpreted by humans, so the use of SPARQL requires an interface that allows the user to enter the queries and display the results in a meaningful way [10]. As with traditional database languages such as SQL, those interfaces are common so that the queries are constructed and launched through forms that do not require the human user to have any knowledge of RDF and SPARQL. Fig 8 displays all the classes, subjects and objects. In a development environment, a user can utilize any components of an ontology by accessing with SPARQL query language programmatically.

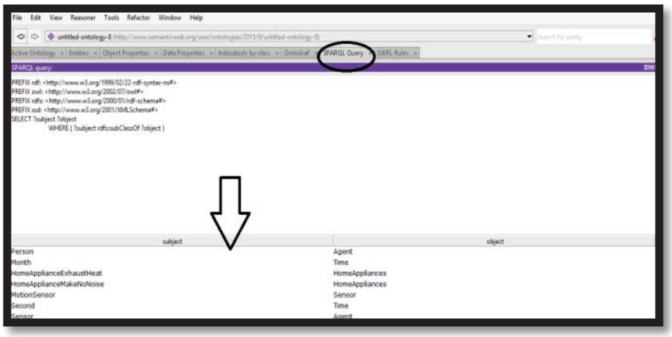

Fig 8: SPARQL query to extract the subject and objects

Fig 9 shows the individuals, types and classes that have been introduced in the home ontology and displays the results based on class. This evaluation query advocates the accuracy of the data engine in ontology. Likewise the previous query example, a developer can extract and utilize the individuals from home ontology. For instance, if an application is designed where a developer would like to control a device he/she can access the individual's list from home ontology and further utilize to perform a specific job.

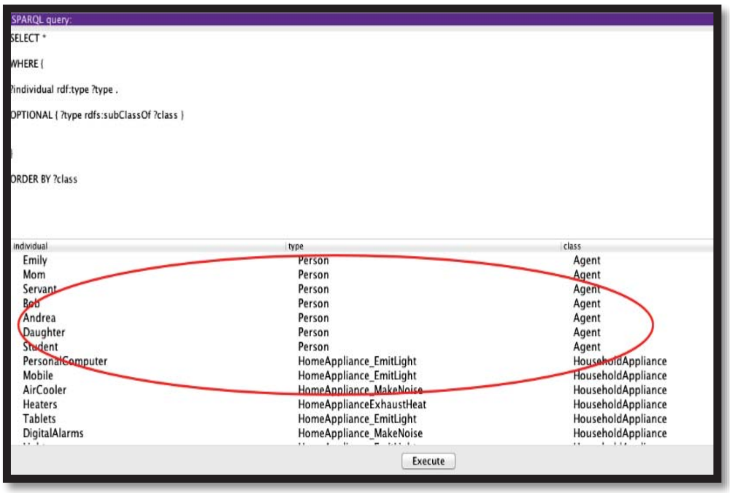

Fig 9: SPARQL query to extract the individuals, types and classes from home ontology

Fig 10, present a specialized query, which extracts the individuals, and their types where the home appliances make noise and emit lights. The results yielded by this query display that all the instances are properly linked with the respective classes.

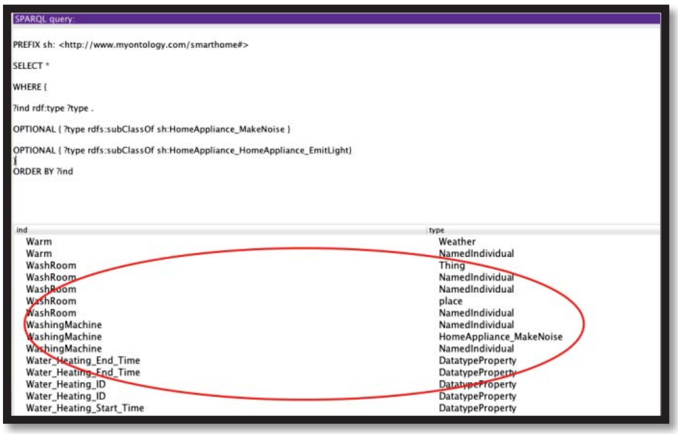

Fig 10: SPARQL query to extract the individuals their types

viii. Conclusion

The smart home ontology was designed to provide the semantic modeling in a smart home environment. The application that would be designed based on this ontology will save the overall electric usage. The researcher has utilized protégé to develop the ontology and SWRL tab to introduce the semantic web rules. Furthermore, the researcher has configured Pellet an inference engine along with SPARQL query engine. Results that have generated in the form of inference and SPARQL query results highlights the correctness of the ontology. The ontology development is different from all the available ontologies based on its approach. Instead of adding the home appliances as sub classes, the researcher has grouped them based on their functional properties. With this approach, any kind of home appliances can be semantically defined. On the other hand, the available ontologies can merely cover a specific portion of a smart home.

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