Development of new ontological solution for an energy intelligent management in Adrar city

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Abstract

Currently, the energy consumption growth presents the fears of post-hydrocarbon and environmental pollution. An important part of the consumed energy is used in residential buildings. The residents of these buildings face significant difficulties to control the consumed power due to several instabilities such as climate change and human behavior. These factors lead to high-energy consumption. Therefore, it is necessary to have a decision tool that optimizes the consumed energy and ensures an acceptable comfort for the residence occupants. This article presents an intelligent solution based on the ontology to present knowledge about the internal and external environment of a residence, as well as the resident behavior and activities. The system openness with the external environment, the knowledge presentation flexibility (OWL) and the possibility of intelligent reasoning (SWRL) are the main reasons for choosing the ontological approach. The proposed ontology is applied to a real home located in the Adrar city, in the Algerian Sahara. A comparison between two scenarios (with and without the OSEIM intervention) is realized to knowledge the effectiveness of the proposed solution. The obtained results present a significant energy saving of 4,58 %.

Keywords: Energy efficient; Smart home; Ontology; Semantic web rule language; Web ontology language.

Abbreviations:

OSEIM	Ontological solution for energy intelligent management
SWRL	Semantic web rules language
OWL	Ontology web language
ANN	Artificial neural networks
IoT	Internet of things
EH-WSN	Energy harvesting-wireless sensor networks
API	Application programming interface
HES	Hybrid energy systems
DUSE	Development unit of solar equipment
ICT	Information and communication technologies
PCM	Pairwise comparison matrix
MCDM	Multiple criteria decision making
MDA	Millions of Algerian dinars
MW	Megawatt
DL	Description logic
P_{ap}	Nominal power in Watt
T	Duration in Minutes
E_{ap}	Energy consumed by an electrical appliance in watt hour
N	Number of the same appliance
E_{apt}	Total consumed energy in watt hour

NICT	New information and communication technologies

1. Introduction

In recent year's energy efficiency, climate change and sustainability principles have become the axes of research worldwide [1]. Energy efficiency refers to the operating state of a system for which energy consumption is minimized. This term is often associated with several concepts such as smart grid, smart home, and smart city. Smart grids can be defined by four characteristics in terms of the flexibility to manage more finely balance between the energy production and consumption; reliability that improves efficiency and network security; accessibility that promotes the integration of renewable energy sources and reduces the production and consumption costs. A smart home is a set of information electronics and telecommunications technologies used in homes. They aim to provide safety, comfort, energy management and communication functions that can be found in a home. The Smart City is an urban area that uses different electronic data collection sensors to provide information to effectively manage resources and assets, integrates information and communication technologies (ICT) and various connected physical devices. Network (the Internet of Things or IoT) to optimize the efficiency of urban operations and services and connect with citizens. Smart cities have developed to respond to major technological, economic and environmental changes, including climate change, economic restructuring, an aging population and urban population growth.

Big Data is a solution designed to give everyone real-time access to giant databases. It aims to offer a choice to the classic solutions of databases and analysis. This technique has been preferred by many researchers to develop intelligent solutions. Saavedra et al. [2] have presented a review of the intelligent system integration in the development of sustainable energy systems to improve the energy efficiency of these systems. They have indicated that the Big Data application is widely adopted for intelligent housing and energy sector. Wang et al. [3] have presented a new solution based on Big Data and ANN to identify energy consumption patterns of different appliances.

Marinakis et al. [4] have offered an architecture of a Big Data platform that can support the creation, development, maintenance, and operation of smart energy services. This solution can then help energy managers and municipal authorities to manage the energy performance of their facilities [5].

An intelligent system based on Big Data is composed of a set of objects that communicate with each other. This type of technology called IoT becomes important because of the huge data generated by different objects. However, during the development stages of IoT, researchers have many challenges to overcome before standardizing IoT for general use. These challenges include many communication technologies such as Bluetooth, ZigBee, WIFI, etc. In this context, Iqbal et al. [6] have proposed a generic communication architecture includes four main steps, namely 1) a system for discovering and identifying electrical appliances in a house or smart building, 2) the deployment of sensors, 3) the application of the proposed load balancing on devices and sensors, and 4) processing. Data is also processed using Hadoop Ecosystem to maximize efficiency and minimize the time required for data processing. However, a smart city is exploiting sustainable information and communication technologies to improve the quality and performance of urban services for citizens and governments, by reducing the consumption of resources. Khajenasiri et al. [7] have presented a hierarchical IoT architecture to control energy in cities and smart buildings. In this solution, the devices are connected via the internet, which requires a layered architecture in which elements, people and cloud services are combined to facilitate the task of the application. The resilient, reliable, efficient and homogeneous energy and power flow are essential for energizing and powering smart city services. In addition, all these smart services should work seamlessly using the smart grids of electricity, considered one of the most important tools of these cities. For the smart city services to be interconnected and synchronized, Al-Ali [8] has presented the role and importance of the IoT in the renewable energy resources integration into the electrical grid to make the network and communication between more reliable and efficient objects.

A residential environment is a system that is always interacted with objects in the external environment such as the climate conditions that influence positively or negatively the energy consumption. Schieweck et al. [9] have studied the environmental parameters effect on the quality of the indoor air, individual thermal comfort and inhabitants behaviors of the smart homes. They have shown the impact of the external parameters on the house internal environment and energy consumption. The results can help the designers of these systems to make forward estimates of the consumed energy in the future. Arghira et al. [10] have interested for forecasting the energy consumption of homes appliances. They have tested tow basic predictors and proposed a stochastic-based predictor. They have shown that the proposed predictor performs present better results than the others studied predictors. However, this is not effective for some types of energy sources such as the wind turbine because it has a non-controllable behavior. To give solutions to this type of critical situation, Kosunalp et al. [11] have proposed a new approach to predict the wind energy for EH-WSN. The particularity of the proposed approach is to take into account the recent conditions of the energy production profiles. The performance of the proposed algorithm is evaluated using real measures and the results of two energy predictors, EWMA and Pro-Energy.

For a sustainable development, the use of renewable energies has become interesting, knowing the problems related to the transmission of electricity in the remote areas, the energy production system realization cost is very high as well as the instability electricity production. It would be interesting to consider the use of HES, especially with the availability of various energy sources on the same site. Al-Ali et al. [12] have proposed a smart home system with solar power. This solution allows for good management of domestic energy needs and scheduling energy flows during peak and off-peak periods. The energy sources hybridization with the storage system redirects the surplus of energy to other consumers. This will improve the efficiency produced energy and allow a better quality of life, fewer gas emissions, and a reduction of the greenhouse effect and a more sensible management of resources available in the cities [13].

Decision support tools provide relevant answers and facilitate decision-making on various issues involving several possible choices. Various approaches have been proposed to address these issues, KOU et al. [14] have presented a review of the main research topics of the PCM in the period of 2000-2015. In the area of Big Data, all approaches proposed for solving the PCM problems will have big challenges, especially with the increase of the dimension of the size of the matrix. Thereafter, MCDM methods are used by KOU et al. [15] to classify and evaluate the quality of classification algorithms in the field of financial risk analysis, taking into account all performance criteria. Since the evaluation of classification algorithms usually involves several criteria, they can be modeled as an MCDM problem. Results demonstrate the effectiveness of MCDM methods in evaluating grouping algorithms and evidence that the repeated bisection method leads to good two-way grouping solutions on financial risk datasets. Then to resolve disagreements between these methods on the basis of Spearman's rank correlation coefficient. Five MCDM methods were examined by KOU et al. [16] that have used 17 classification algorithms and 10 performance criteria on 11 public domain binary classification datasets. The experimental results show that this approach can resolve MCDM conflict rankings and reach an agreement and compatible ranking between the different MCDM methods.

Developments and research in residential automation are in full swing, especially for the connectivity between objects (Internet of Things). The home automation market is expected to grow steadily to reach 116,26 billion US dollars by 2026, compared to 64,67 billion US dollars in 2017 [17]. Home automation has experienced new technological advances in developed countries, particularly in United States and Europe, in the form of smart home automation. This is considered an important factor driving the growth of the home automation market in North America and Europe. In addition, the market for domotic products and solutions in other countries has encountered a growing in popularity due to the significant increase in disposable income. The 5 top home automation markets according to Statistac [18] are:

Table 1. The 5 top country's on the home automation markets

Country	Home automation market (USD)
United States	6021,7
Japan	729,0
Germany	600,2
China	323,6
United Kingdom	303,5

To date, only one prototype of a smart home exists in Algeria that is developed by the research team of the solar equipment development unit in the Tipaza city [19]. This prototype is considered a demonstration platform for university students, teacher-researchers. The work that we wish to accomplish is a solution for the management of a house located in the city of Adrar in Algeria. This contribution is considered as the first study carried out at the level of Adrar city. In addition, it is interesting from economic and ecological points of view because of the great saving of energy consumed. Finally, the realized tool can be considered as a means of orientation and awareness to rationalize energy consumption and can be used as a demonstration platform for students, researchers and university teachers.

The paper is organized as follows: Section 2 describes the design and development of OSEIM. Section 3 presents the case study and simulation, and the environment of OSEIM, the scenarios of energy consumption. Section 4 analyses the obtained results after the intervention of the OSEIM, and some observations and discussions are presented in this section. Finally, Section 5 concludes the paper with summaries and future research directions.

2. ENERGY STATISTICS IN ALGERIA

2.1. Statistics on electricity production

The electricity production at Algeria in 2015 and 2016 is estimated by 97,7 Twh, when 31,4 Twh in 2015 and 66,3 Twh in 2016, which represents an increase of 2,4% [20]. This production regroups the subsidiaries of the Algerian company of electricity and gas (Sonelgaz) with 47,4%, and the other national producers with 52,6%. For the future programs, the Algerian State has programmed a production of 21,307 MW for the period 2017-2027. For the same period, 34441 km of electrical lines were scheduled to install. Thus, the total length of the electricity transmission network will reach 60790 km in 2027 for an investment of 1588740 MDA (Millions of Algerian Dinars).

2.2.Statistic of renewable energies in Algeria

Algeria is recognized by an important type of renewable energy, particularly solar energy, whose lighting duration exceeds 2500 hours on national average and can reach 3900 hours (especially in the Sahara) which allow diversifying the production sources of electricity [20]. The Algerian State has given great importance to the exploitation and development of the renewable energies, the objective is fixed achieving electricity production from renewable sources around 37% [21]. Finally, for the national renewable energy development project 2015-2030. It is expected to reach 22000 MW of electricity in 2030 [20].

2.3.Statistic of electricity production in Adrar

Due to the importance of the solar irradiation in Algeria, especially in Adrar region, Algeria has launched several electricity generation projects in this region. The total installed capacity during the period (2015-2017) is estimated at 88 MW shared over 7 sites (Table 2) [22,23].

Table 2. Electricity production based solar-photovoltaic for the period 2015-2017 in the Adrar region.

Central	Installed capacity (MW)	The year of operationalization
Kabertene (Adrar)	3	2015
Adrar (City)	20	2015
Aoulef (Adrar)	5	2016
Reggane (Adrar)	5	2016
Timimoune (Adrar)	9	2016
Z. Kounta (Adrar)	6	2016

Sali (Adrar)	40	2017
The total installed	**88**	

The Algerian renewable energy program (2015-2030) considered the wind energy as the second source that represents 3% of electricity production in 2030 [21]. In the research area, Algeria plans to install some research projects of renewable energies, such as biomass technology, geothermal energy and desalination of brackish water, for future investments. The important axis area are the photovoltaic and thermal solar energies and the wind power.

2.3.1. Photovoltaic solar energy

The Algerian state plans to launch solar energy projects with a total capacity of 800 MW by 2020. Other projects with a capacity of 200 MW are scheduled for the period 2021-2030 [21].

2.3.2. Thermal solar energy

In the 2011-2013 period, two thermal power plants with a capacity of 150 MW were launched. A third project was lanced thereafter, the hybrid power plant at Hassi R'Mel that has a capacity of 150 MW, 25 MW in photovoltaic solar energy and 125 MW by other energy sources [21]. Four solar thermal plants with a capacity of 1200 MW are programmed to commission in 2016-2020. Finally, this program provides for the installation of 500 MW/year until 2023, then 600 MW/year until 2030.

2.3.3. Wind power

The The first wind station in Adrar was commissioned in 2013 with a capacity of 10 MW. Then, between 2014 and 2015, two stations with a capacity of 40 MW are built. Localization studies of others projects are realized to reach a production of 1700 MW by 2030 [21].

3. OSEIM DESIGN AND DEVELOPMENT

A home is considered as an open system that constantly interacts with the external environment. This system includes a large informational volume that is in need of representation and structuring, which represents a very problematic. To proceed of the solving, the choice of the ontology of the domain as approach leans on the facility of using of the solution, good representation of the information, flexibility in the update of the information and sharing of knowledge between different users.

The ontology "is a formal, explicit specification of a shared conceptualization" [24,25]. Formal refers to the fact that the ontology should be machine-readable. Explicit means that the type of used concepts and the constraints on their use are explicitly defined. Shared reflects that ontology is not private of some individual. Conceptualization refers to an abstract model of some phenomenon.

The ontological approach includes a *Class* to represent the objects, a *Relation* that concerns the association between two or more classes, *Attribute* to give a clear description for the classes, *Axioms* to model the sentences which are always true and finally the *Instances* to represent the individuals.

For the design and development of OSEIM, we have based on the methods proposed by [23,26,27] that consist of several steps (Figure 1).

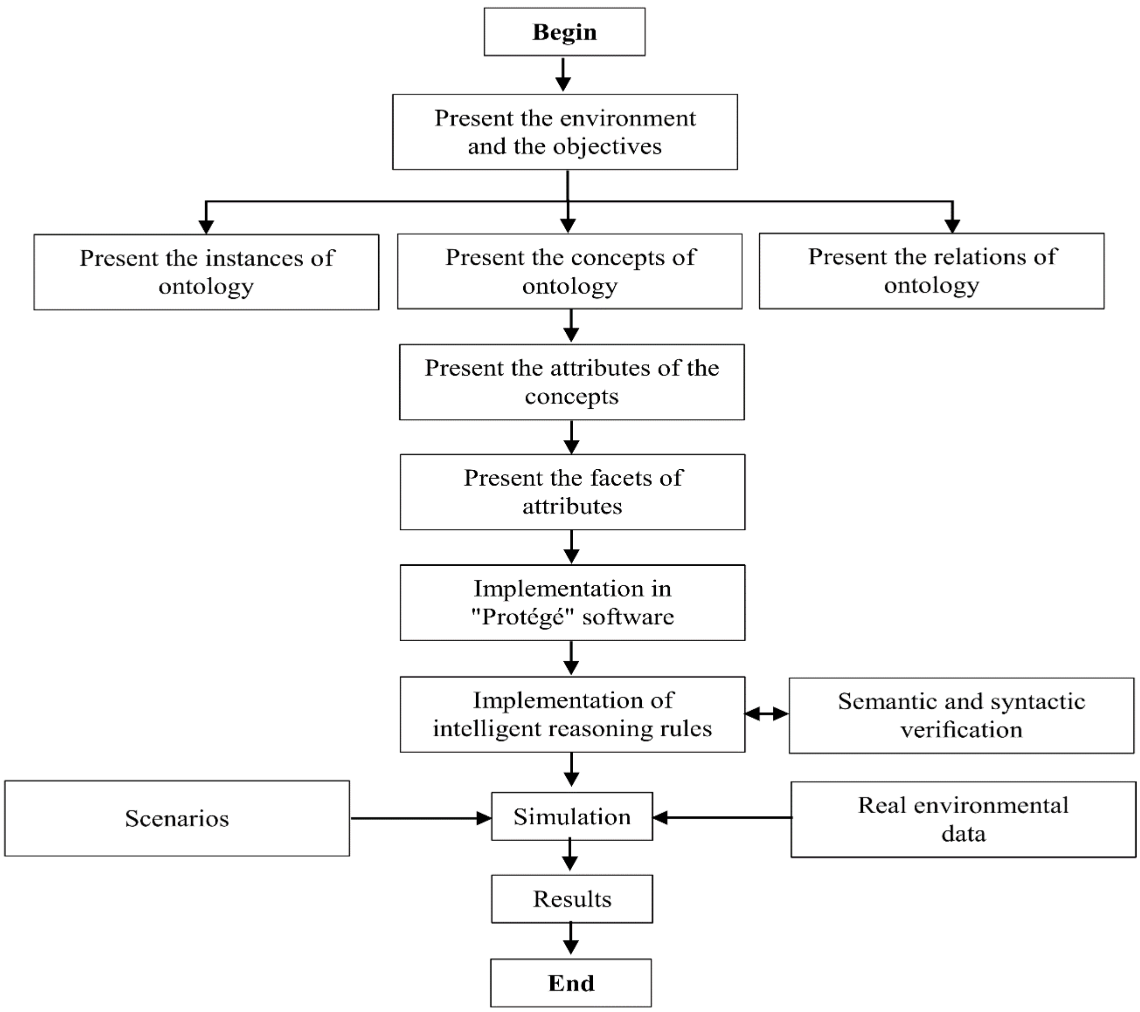

Fig. 1. Flowchart of the proposed method for the OSEIM design and development

3.1.Presentation of the environment and objectives

The studied environment in this work is a housing includes different types of objects (appliances, occupants ...). This environment needs automation and management to realize a saving energy.

3.2.Presentation of the ontology concepts

Several works have been done on the intelligent management of houses and daily life of the occupants. In this work, we are interested in concepts that are useful to achieve the OSEIM goal. This section is intended to answer a series of questions: what are the properties of these concepts? What is the meaning of concepts?

The classes are similar to the concepts in object-oriented programming and form a hierarchy [27], which are developed by methods and approaches [28]. In our study, we will propose a new method that is based on importing knowledge from existing ontologies to define the interesting concepts. Table 3 presents some examples of OSEIM concepts.

Table 3. Some examples on OSEIM concepts

Concept	**Concept description**
Occupant	Represents the home occupants [29]
Building	Represents a home. It is the highest concept in the ontology hierarchy [30]
Place	Represents an place in the home [31]
Appliance	Represents the existing appliances in the house or in its environment [32]
Activity	Represents the activities of occupants [29]

3.3.Ontology relations

A relationship represents an association between two or more concepts. Table 4 shows an excerpt from ontology relations.

Table 4. Examples on ontology relations

Relationship	**Description**	**Associated concepts**

PlaceHasAppliance ("")	Each area (room) in the home includes electrical appliances	Place, Appliance
OccupantHasActivity ("")	An occupant of the house has one or more activities	Occupant, Activity
ApplianceHasAction ("")	Each electrical equipment that characterized by one or more actions	Appliance, Action
EnvironmentParamaters ("")	The home environment that characterized by climatic data	Environment, Paramaters
OccupantHasProfil ("")	An occupant of the house that characterized by a personal profile	Occupant, Profil

3.4.Attributes of the concepts

In this section, we will present the internal description of the concepts (attributes). Table 5 shows some examples of the attributes.

Table 5. Extract of the ontology concept attributes

Attribute	Description	Concept
OccupantName	The occupant name	Occupant
activityName	The activity name	Activity
sizeOfRoom	The surface of a room in the home	Place
behaviorName	The name of the occupant behaviour	Behavior
powerRating	The nominal power of the electrical equipment	Appliance

3.5.Ontology instances

An individual represents an abstract description of a concept. Table 6 shows an excerpt from the OSEIM ontology.

Table 6. Extract ontology individuals

Instances	Concept
Laptop	Appliance
Electric clock	Appliance
Mobile phone	Appliance

Living room	Place
KidsRoom	Place
DiningRoom	Place

3.6.Facets of attributes

The attribute facet shows the types of values that can be assigned to the attribute (Table 7).

Table 7. Extract on facets of attributes

Data-type-property	Description	Concepts
firstName	Alphabetical	Occupant
powerRating	Numeric	Appliance
activityName	Alphabetical	Activity
behaviorName	Alphabetical	Behavior
sizeOfRoom	Numeric	Place

3.7.Implementation in "Protégé" software

For the data edition (Concepts, attributes, relations, instances ....), we have used the "Protégé" software, version 3.4.4. This software provides an application-programming interface (API), which allows JAVA developers to program applications that can access "Protégé" knowledge bases, and provides packages and JAVA classes that can perform all operations. The interface of "Protégé" is done using the class "edu.standford.smi.protege.model.Project" which is in the package "protege.jar" provided with "Protégé 3.4.4" [33]. This class has a getKnowledgeBase () method to access knowledge base content. Once the project is created, we need to create the ontology classes. Then, it is important to present the properties (or locations) of all concepts. Once all the concepts with these internal descriptions have been created, the next step is to create the associations between the concepts. Finally, each concept can have multiple individuals. Figure 2, 3, and 4 shows the important elements of ontology.

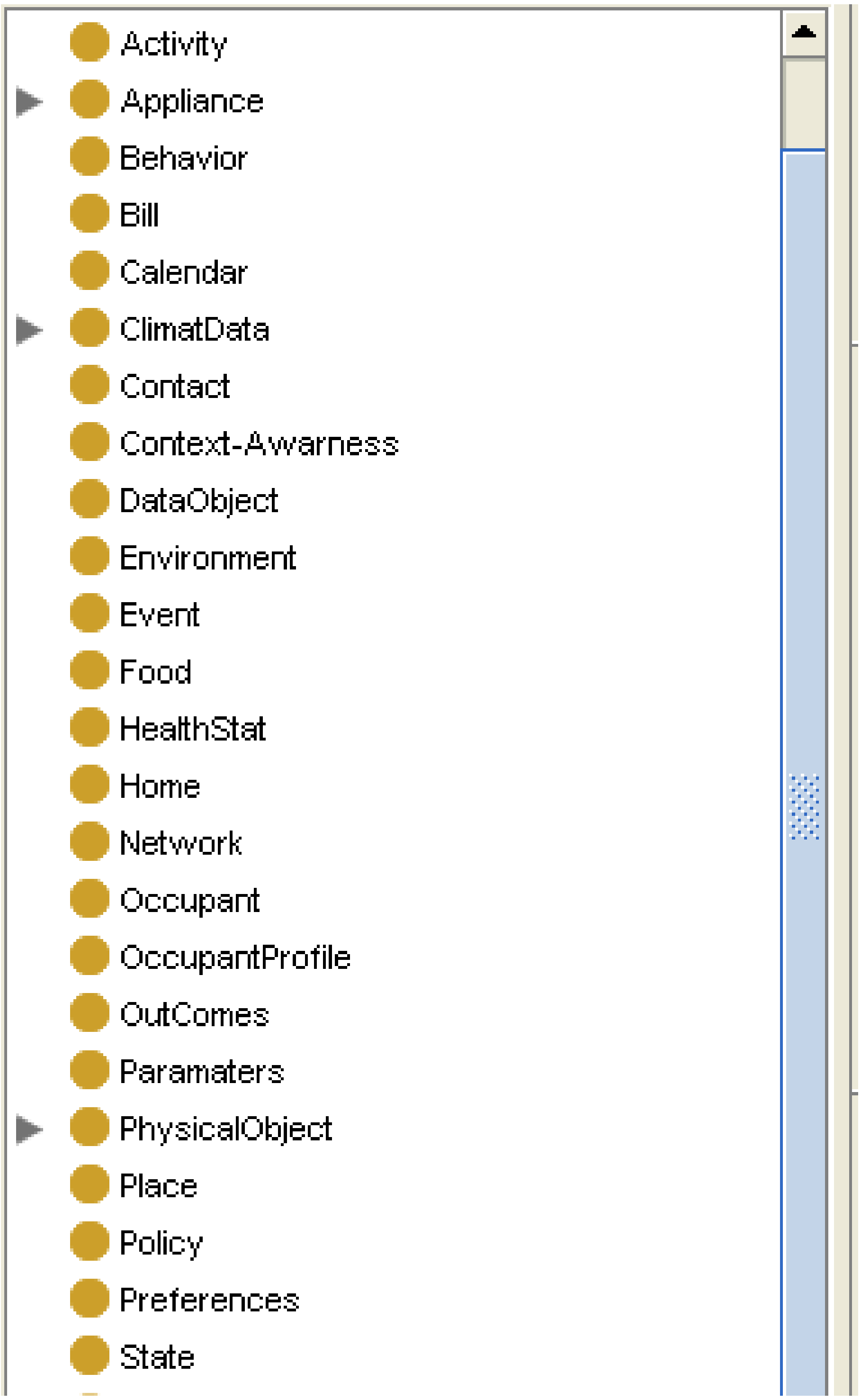

Fig. 2. Classes in "Protégé" software

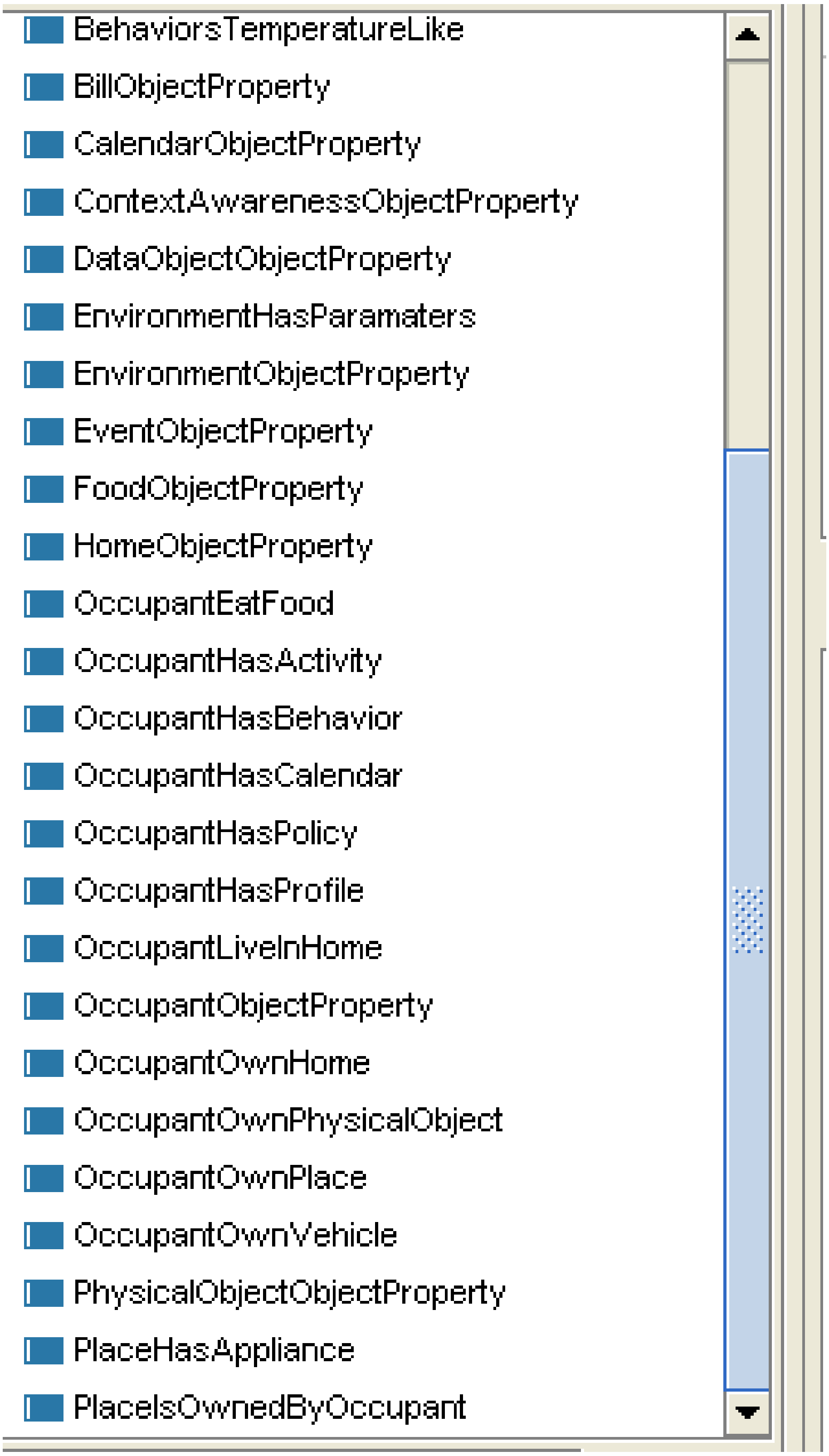

Fig. 3. Properties in "Protégé" software

Fig. 4. Instances in "Protégé" software

3.8.Implementation of intelligent reasoning rules

The OSEIM based on intelligent reasoning that is formulated by rules. All rule is loaded for the accomplishment of a task. In this section we will present some rules (Figure 5).

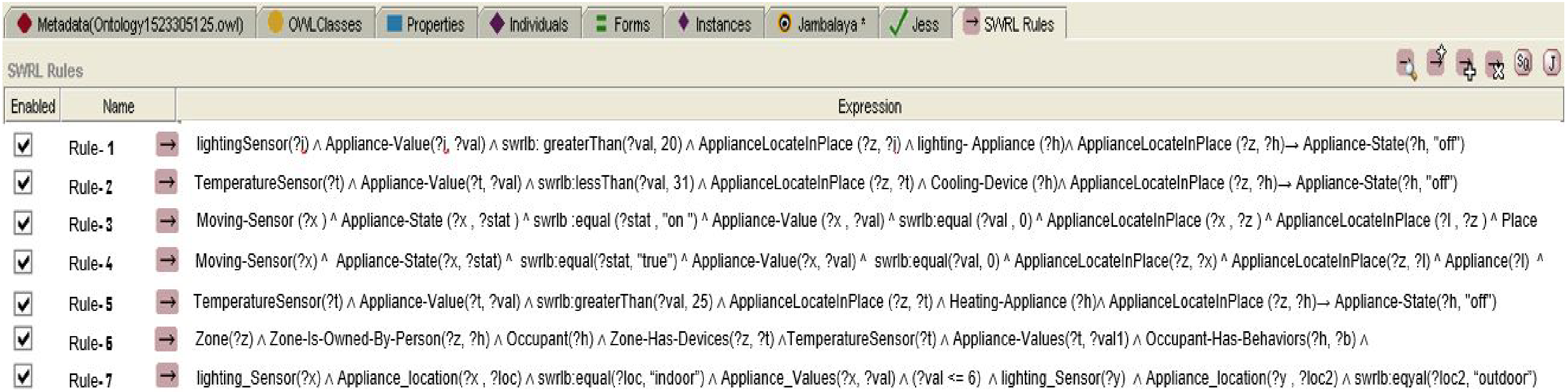

Fig. 5. Reasoning rules in "Protégé" software

lightingSensor(?i) ∧ Appliance-Value(?i, ?val) ∧ swrlb: greaterThan(?val, 20) ∧ ApplianceLocateInPlace (?z, ?i) ∧ lighting-Appliance (?h)∧ ApplianceLocateInPlace (?z, ?h)→ Appliance-State(?h, "off")

(R1)

This rule allows you to turn off the lights in a room (zone) of the house if the external lighting (sun) is sufficient (for this study, greater than 20 Linux).

TemperatureSensor(?t) ∧ Appliance-Value(?t, ?val) ∧ swrlb:lessThan(?val, 31) ∧ ApplianceLocateInPlace (?z, ?t) ∧ Cooling-Device (?h)∧ ApplianceLocateInPlace (?z, ?h)→ Appliance-State(?h, "off")

(R2)

This rule is used to stop the cooling systems at a temperature value below of 31°C.

Moving-Sensor (?x) ^ Appliance-State (?x , ?stat) ^ swrlb :equal (?stat , "on ") ^ Appliance-Value (?x , ?val) ^ swrlb:equal (?val , 0) ^ ApplianceLocateInPlace (?x , ?z) ^ ApplianceLocateInPlace (?l , ?z) ^ Place (?z) ^ Light(?l) ^ Appliance-State (?l , ?stat 2) ^ swrlb :equal (?stat 2, "on ") -> Appliance-State (?l , "of ") ^ Turn - Of (?l)

(R3)

This rule turns off all lamps in an area. In case of total absence of the occupants.

Moving-Sensor(?x) ^ Appliance-State(?x, ?stat) ^ swrlb:equal(?stat, "true") ^ Appliance-Value(?x, ?val) ^ swrlb:equal(?val, 0) ^ ApplianceLocateInPlace(?z, ?x) ^ ApplianceLocateInPlace(?z, ?l) ^

```
Appliance(?l) ^ Appliance-State(?l, ?stat2) ^ swrlb:equal(?stat2, "on") ->
Appliance-State(?l, "off") (R4)
```

This rule is used to stop all devices in case of total absence of occupants.

```
TemperatureSensor(?t) ∧ Appliance-Value(?t, ?val) ∧
swrlb:greaterThan(?val, 25) ∧ ApplianceLocateInPlace (?z, ?t) ∧
Heating-Appliance (?h)∧ ApplianceLocateInPlace (?z, ?h)→ Appliance-
State(?h, "off") (R5)
```

This rule turns off the heating in a room in the house if the ambient temperature reaches 25 °C.

```
Zone(?z) ∧ Zone-Is-Owned-By-Person(?z, ?h) ∧ Occupant(?h) ∧ Zone-
Has-Devices(?z, ?t) ∧TemperatureSensor(?t) ∧ Appliance-Values(?t,
?val1) ∧ Occupant-Has-Behaviors(?h, ?b) ∧
BehaviorsTemperatureLike(?b) ∧ BehaviorsTemperatureVal(?b,?val2) ∧
swrlb:greaterThan(?val1,?val2) ∧ Zone -Has-Appliance(?z,?c) ∧
Cooling(?c) → Appliance-State(?c ,"on") ∧ Appliance-Values(?c,?val
2) (R6)
```

This rule allows to turn on the cooling appliances in a room (zone) of the house according to the wishes of the occupant.

```
lighting_Sensor(?x) ∧ Appliance_location(?x , ?loc) ∧
swrlb:equal(?loc, "indoor") ∧ Appliance_Values(?x, ?val) ∧ (?val <=
6) ∧ lighting_Sensor(?y) ∧ Appliance_location(?y , ?loc2) ∧
swrlb:eqyal(?loc2, "outdoor") ∧ Appliance_Values(?y, ?val2) ∧
swrlb:greaterThan(?val2?,20) ∧ ApplianceHasLocation(?x,?z) ∧
ApplianceHasLocation(?y,?z) ∧ Light(?l) ∧
```

```
ApplianceHasLocation(?l,?z) ∧ window(?w) ∧
ThingHasLocation(?w,?z)→ Appliance_Stat(?l, "of") ∧
window_state(?w,"open")
```
(R7)

This rule opens the windows of a room in the house when outside lighting is acceptable.

3.9.Semantic and syntactic verification

Other operations such as integrating new classes into the ontology can potentially produce semantic inconsistencies. To this end, Jean-Mary et al. [34] have proposed a solution concerning the use of lexical and structural characteristics between ontologies to verify the existence of semantic anomalies. Abanda et al. [35] have distinguished two methods to discover the semantic anomalies, the first is manual consisting of a visual reading against and the second is automatic. For the ontology of this study, an automatic verification is carried out using a reasoned DL on OSEIM that based on the use of Pellet 1.5.2 reasoning. This choice is guided by the availability of the Pellet 1.5.2 reasoning plug-in integrated with Protégé-OWL 3.4.4. Both methods involve repetitive processes until no more anomalies can be identified. For OSEIM, no error has occurred and the so-called syntactically verified ontology (Figure 6).

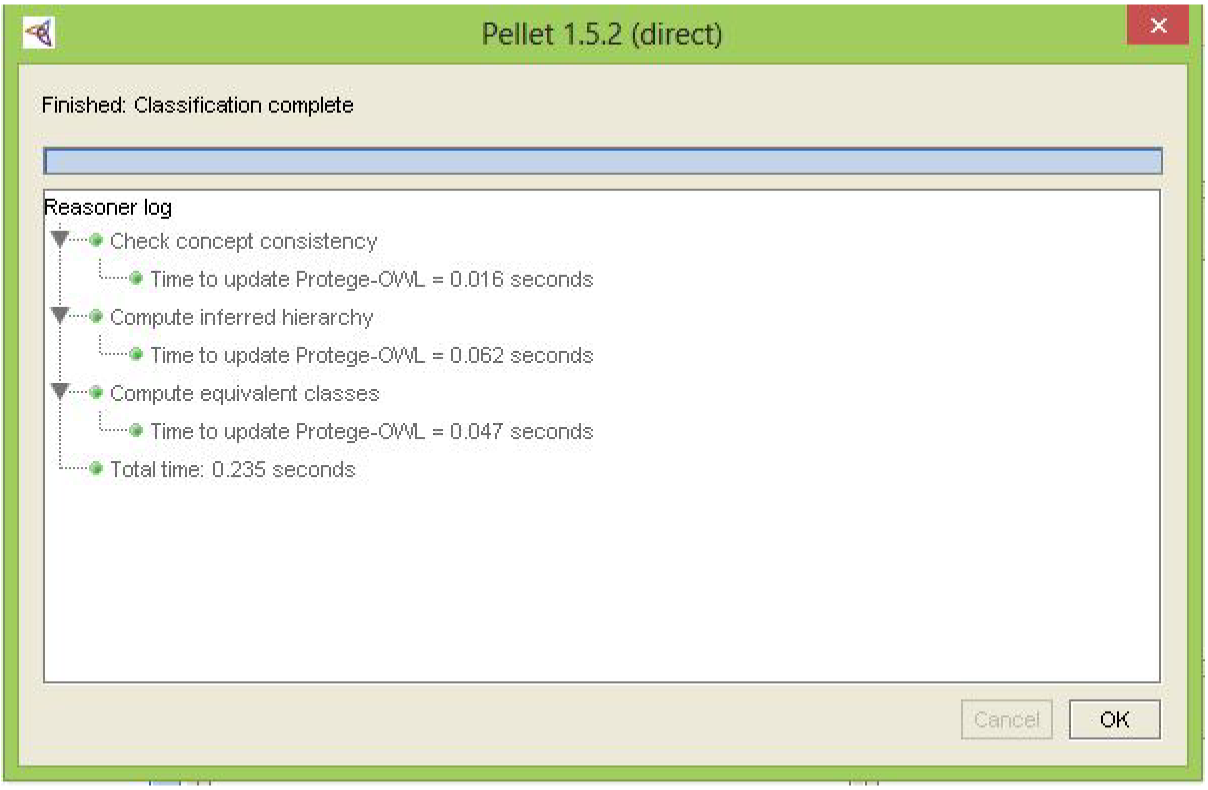

Fig. 6. Semantic and syntactic verification

4. CASE STUDY AND SIMULATION

This section is reserved for presenting the internal and external environment of the house concerned by this study and focus on the elements that consume energy (appliances) and the elements that influence the energy consumption (climate data, activities of occupants ....). Then we present two scenarios of energy consumption, the first concerns the usual consumption (without the OSEIM intervention), and the second presents consumption with the intervention of OSEIM.

4.1.Presentation of the environment

OSEIM is tested on a house in the city of Adrar in Algeria. The city of Adrar is located in the extreme south of Algeria and 1500 km from the capital Algiers (Figure 7). It is characterized by a latitude: 27 ° 52'27 "N, a longitude: 0 ° 17'37" W and a elevation above sea level: 257 m = 843 ft [36–39]. This home is resided by an nine-member family (grandfather, grandmother, father, mother and five children). The general architecture of the home is illustrated in Figure 8.

Fig. 7. Geographical situation of Adrar city

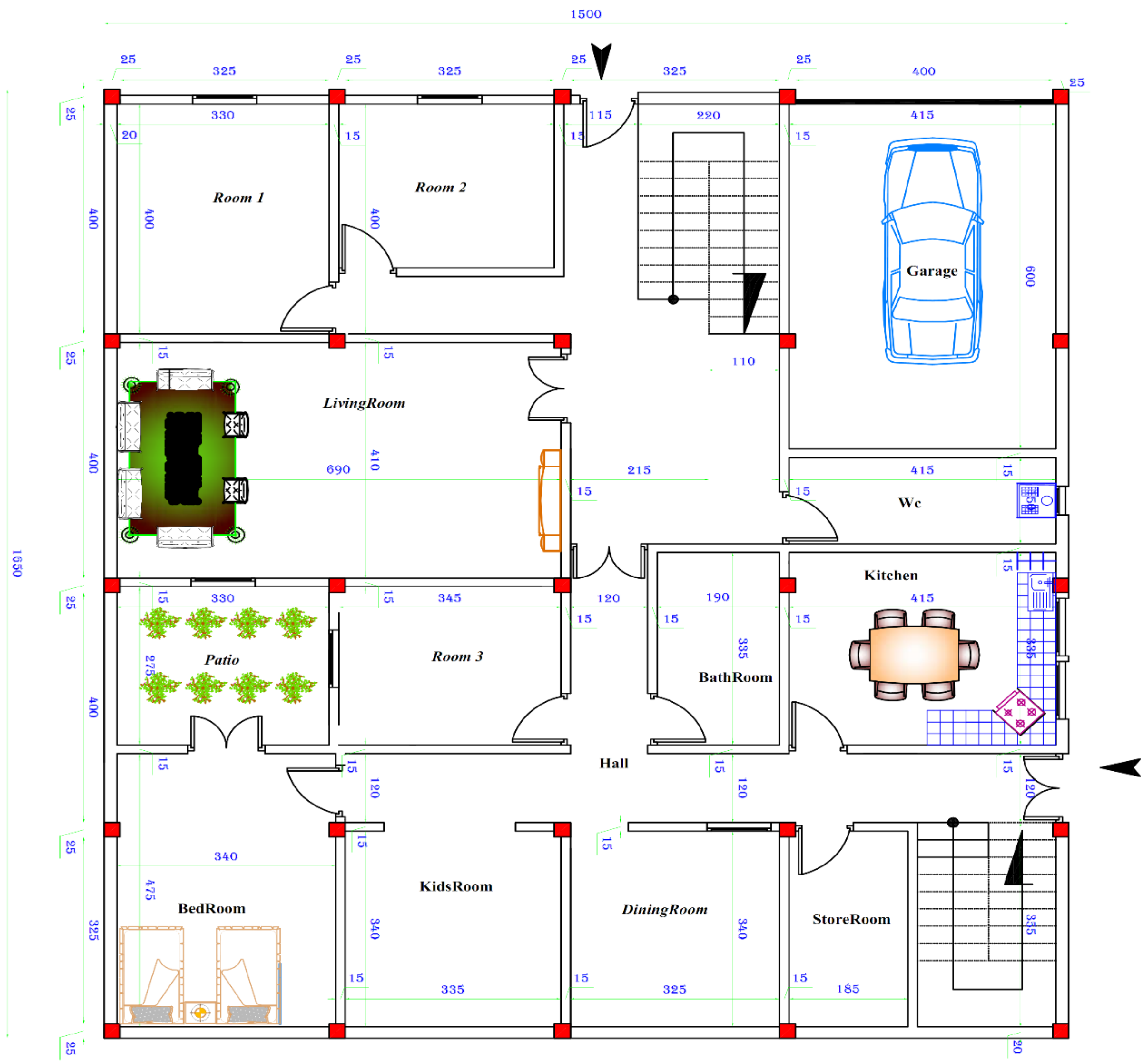

Fig. 8. Home architecture

Adrar has a hyper-arid hot desert climate, with scorching and very long summer, and a short and warm winter.

The average maximum temperatures are 46 - 48 ° C in July, making Adrar one of the hottest cities in the world. The peak-temperature record was established on Monday, July 9, 2018 with a temperature of 65 ° C [40].

The average number of days when the mercury exceeds the 40 ° C mark is of the order of 130 days per year. Temperatures remain high in winter but only during the day, because in the desert areas, there is nothing to retain the heat and average minimum temperatures are around 7 ° C. The sky is clear, the sun is omnipresent, the beautiful perpetual weather. Solar irradiation is among the highest in the world and the average duration of sunstroke is about 3 978 hours per year [41]. The ratio in percentage between the duration of the day and the duration of annual sunshine exceeds 90%. The average annual daily temperature is 26-27 ° C in Adrar.

The relative humidity is exceptionally low all year round with an annual average of around 24%, and especially in the hot season when the hygrometric degree of the air often drops below 5%.

The home is included a range of electrical appliances. Table 8 presents some examples of electrical appliances and its power ratings and number in the house spaces.

Table 8. Electrical appliances list

Room (area)	**Electrical appliance**	**Number (N)**	**Power (p_{ap})**
Kitchen	Light (Economic lamp)	2	25
	Dishwasher	1	1200
	Refrigerator combi (250L)	1	175
	Microwave	1	1125
	Electric oven (Classic oven)	1	2000
	Electric mixer	1	300
	Coffee-maker	1	900
	Electric water boiler	1	3000
	Vacuum Cleaner (Mobile)	1	800
	Ceiling fan (Diameter 122 cm)	1	60
	Air exchanger	1	350
Living room	Light (Economic lamp)	3	25
	TV LCD (80 cm)	1	150
	Parabolic demodulator	1	20
	Air conditioner (8000 BTU)	1	900
	Home internet router	1	7
	PlayStation 4 (PS4)	1	50

Garage	Light (Economic lamp)	4	25
	Electric car	1	3000
	Camera	1	20
	Lawnmower	1	1250
Hall	Light (Economic lamp)	3	25
Room	Light (Economic lamp)	2	25
	Desktop	1	80
	Laptop	1	50
	Air conditioner (6000 BTU)	1	700
	Clock radio	1	5
	Iron	1	800
WC	Light (Economic lamp)	2	25
Bathroom	Light (Economic lamp)	2	25
	Electric water boiler	1	1800
	Washing machine (Cold water)	1	240
	Submersible-water-pump	1	1000
	Electric shaver	1	12

4.2.Scenarios of energy consumption

To test OSEIM, both scenarios (with and without the intervention of the solution) during the day 1 July 2018 are taken into consideration and examined.

4.2.1. Without OSEIM intervention

Overview of the daily energy consumption (energy consumed over a period of one hour) is presented in Tables 9, 10, 11, 12, 13 and 14. All tables are accompanied by climatic data that characterize the environment. (Horizontal Radiation (W / m^2), Temperature (° C), Humidity (%)) [42]. To calculate the energy consumed by an electrical appliance of nominal energy (P_{ap} (W)) and a duration (T (Hours)), we use the following formulas:

$$E_{ap}(Wh) = P_{ap} . T \quad (1)$$

If a place of the home contains a number of the same appliance (N), the calculate of the consumed energy is given as:

$$E_{apt}(Wh) = E_{ap}.N \qquad (2)$$

The total energy is calculated as:

$$E_t(\mathrm{W}\,h) = \sum_{i=1}^{n} E_{apt}(i) \qquad (3)$$

Where "*i*" is appliance type

Finally, we mention that the energy consumed by event (Watt/h) is calculated by the formula (3), the energy consumed per hour (Watt/h): is the sum of energy consumed by all members of the family during one hour. The home occupants set the air conditioner to 25 and the electric heater to 30 degrees without checking the room temperature.

Table 9. Energy consumption scenario during the period: 00h: 00m: 00s - 00h: 59m: 59s

Time (h, m, s)	Family Member	Place	Event - Activity	Action	Devices in operation
00h:00m:00s - 00h:59m:59s	GrandFather	Room1	Sleeping	Nothing	Air conditioner (6000 BTU)
	GrandMather	Room1	Sleeping	Nothing	
	Father	BedRoom	Sleeping	Nothing	Air conditioner (6000 BTU)
	Mather	BedRoom	Sleeping	Nothing	
	Brother-1	Room2	Sleeping	Nothing	Air conditioner (6000 BTU)
	Brother-2	Room2	Sleeping	Nothing	
	Sister-1	Room3	Sleeping	Nothing	Air conditioner (6000 BTU)
	Sister-2	Room3	Sleeping	Nothing	

Table 10. Energy consumption scenario during the period: 00h: 00mn: 00s - 00h: 59mn: 59s (Continuation of Table 9)

Devices in operation	Number (N)	Operating time (Minutes)	Power (W)	Energy consumed by event (W)	Energy consumed per hour (W)
Air conditioner (6000 BTU)	1	60	700	700,00	2800,00
Air conditioner (6000 BTU)	1	60	700	700,00	

Air conditioner (6000 BTU)	1	60	700	700,00
Air conditioner (6000 BTU)	1	60	700	700,00

The average values of the climate data during the period from 00h: 00m: 00s to 00h: 59m: 59s are: horizontal radiation (W/m2): 0, temperature36,29°C and humidity 6,567% [42]

Table 11. Energy consumption scenario during the period: 13h: 00m: 00s - 13h: 59m: 59s

Time (h, m, s)	Family Member	Place	Event - Activity	Action	Devices in operation
13h:00m:00s - 13h:59m:59s	GrandFather	Room1	Sleeping	Nothing	Air conditioner (6000 BTU)
	GrandMather	Room1	Sleeping	Nothing	
	Father	Out of the house	At work	/	/
	Mather	BedRoom	Sleeping	Nothing	Air conditioner (6000 BTU)
	Brother-1	Out of the house	At school	/	/
	Brother-2	DiningRoom	Go to DiningRoom	Lunch	Air conditioner (8000 BTU)
	Sister-1	Out of the house	At school	/	/
	Sister-2	DiningRoom	Go to DiningRoom	Lunch	/

Table 12. Energy consumption scenario during the period: 13h: 00mn: 00s - 13h: 59m: 59s (Continuation of Table 11)

Devices in operation	Number (N)	Operating time (Minutes)	Power (W)	Energy consumed by event (W)	Energy consumed per hour (W)
Air conditioner (6000 BTU)	1	60	700	700,00	2300,00
/	0	0	0	0	
Air conditioner (6000 BTU)	1	60	700	700,00	
/	0	0	0	0	
Air conditioner (8000 BTU)	1	60	900	900,00	
/	0	0	0	0	
/	0	0	0	0	

The average values of the climate data during the period from 13h: 00m: 00s to 13h: 59m: 59s are: horizontal radiation 1043,67 W/m2, temperature 44,99 °C and humidity 4,307 % [42].

Table 13. Energy consumption scenario during the period: 16h: 00m: 00s - 16h: 59m: 59s

Time (h, m, s)	**Family Member**	**Place**	**Event - Activity**	**Action**	**Devices in operation**
16h:00m:00s - 16h:59m:59s	GrandFather	Out of the house	Take a tour of the city	Go to Garage	Light_Garage
	GrandMather	Out of the house	Take a tour of the city	/	/
	Father	Garage	Return from work and got to Garage	Go to Garage	Light_Garage
		DiningRoom	Return from work and got to DiningRoom	Have an evening coffee meal	Air conditioner (8000 BTU) Light_DiningRoom
	Mather	BedRoom	Go to the BedRoom	Prepare for a walk out	Air conditioner (6000 BTU) Light_BedRoom
	Brother-1	Room2	Go to the Room2	Prepare for a walk out	Air conditioner (6000 BTU) Light_Room2
	Brother-2	Room2	Go to the Room2	Prepare for a walk out	Air conditioner (6000 BTU) Light_Room2
	Sister-1	Room3	Go to the Room3	Prepare for a walk out	Air conditioner (6000 BTU) Light_Room3
	Sister-2	Room3	Go to the Room3	Prepare for a walk out	Air conditioner (6000 BTU) Light_Room3

Table 14. Energy consumption scenario during the period: 16h: 00m: 00s - 16h: 59m: 59s (Continuation of Table 13)

Devices in operation	**Number (N)**	**Operating time (Minutes)**	**Power (W)**	**Energy consumed by event (W)**	**Energy consumed per hour (W)**
Light_Garage	2	10	25	8,33	
/	0	0	0	0,00	
Light_Garage	2	5	25	4,17	
Air conditioner (8000 BTU)	1	15	900	225,00	
Light_DiningRoom	2	15	25	12,50	
Air conditioner (6000 BTU)	1	30	700	350,00	
Light_BedRoom	2	30	25	25,00	
Air conditioner (6000 BTU)	1	15	700	175,00	1375,00
Light_Room2	2	15	25	12,50	
Air conditioner (6000 BTU)	1	15	700	175,00	
Light_Room2	2	15	25	12,50	
Air conditioner (6000 BTU)	1	15	700	175,00	
Light_Room3	2	15	25	12,50	
Air conditioner (6000 BTU)	1	15	700	175,00	
Light_Room3	2	15	25	12,50	

The average values of the climate data during the period from 16h: 00m: 00s to 16h: 59m: 59s are : horizontal radiation 712,42 W/m^2, temperature : 45,43°C and humidity 5,404 % [42].

4.2.2. With OSEIM intervention

The obtained results using OSEIM intervention are given in Table 15. These results are based on the intelligent reasoning rules (Figures 9, and 10).

Table 15. The obtained results using OISEM intervention

Time (h, m, s)	**Energy consumption with OISEM intervention**	**Energy saved (W)**	**The rules used by the OSEIM**
00h:00m:00s – 00h:59m:59s	2800,00	0,00	/

01h:00m:00s – 01h:59m:59s	2566,66	0,00	/
02h:00m:00s – 02h:59m:59s	2286,66	0,00	/
03h:00m:00s – 03h:59m:59s	1960,00	0,00	/
04h:00m:00s – 04h:59m:59s	2097,92	0,00	/
05h:00m:00s – 05h:59m:59s	0,00	1633,33	R2, R5
06h:00m:00s – 06h:59m:59s	743,33	1750,00	R2, R5
07h:00m:00s – 07h:59m:59s	0,00	2212,50	R2, R5
08h:00m:00s – 08h:59m:59s	2266,67	0,00	/
09h:00m:00s – 09h:59m:59s	2385,00	100,00	R1
10h:00m:00s – 10h:59m:59s	163,33	100,00	R1
11h:00m:00s – 11h:59m:59s	2232,50	145,83	R1
…	…	…	…
15h:00m:00s – 15h:59m:59s	3912,50	62,50	R1
16h:00m:00s – 16h:59m:59s	1275,00	100,00	R1
17h:00m:00s – 17h:59m:00s	0,00	08,33	R1
…	…	…	…
22h:00m:00s – 23h:00m:00s	85400,00	0,00	/
23h:00m:00s – 23h:59m:59s	2800,00	0,00	/

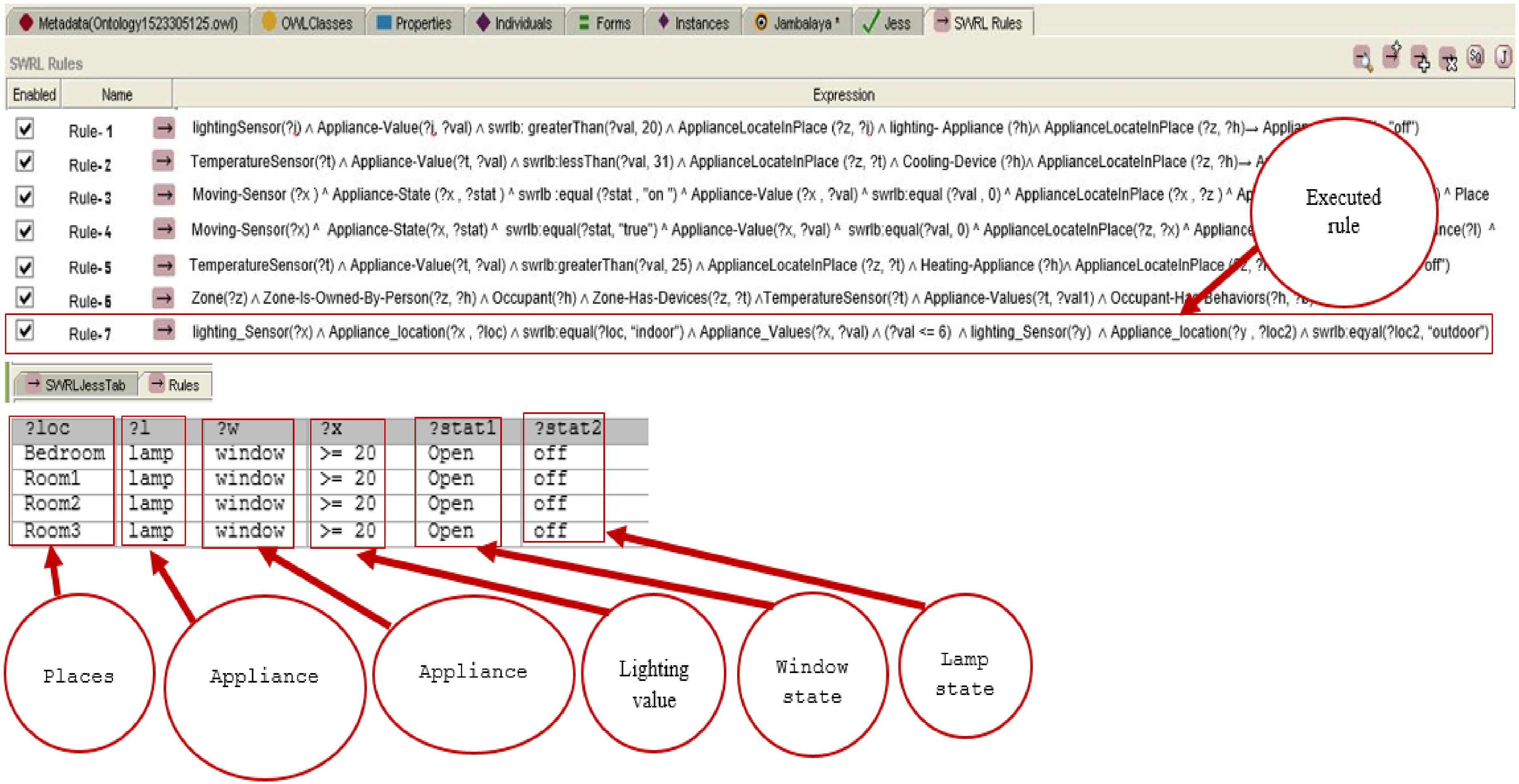

Fig. 9. The windows opening rule, when outside lighting is acceptable

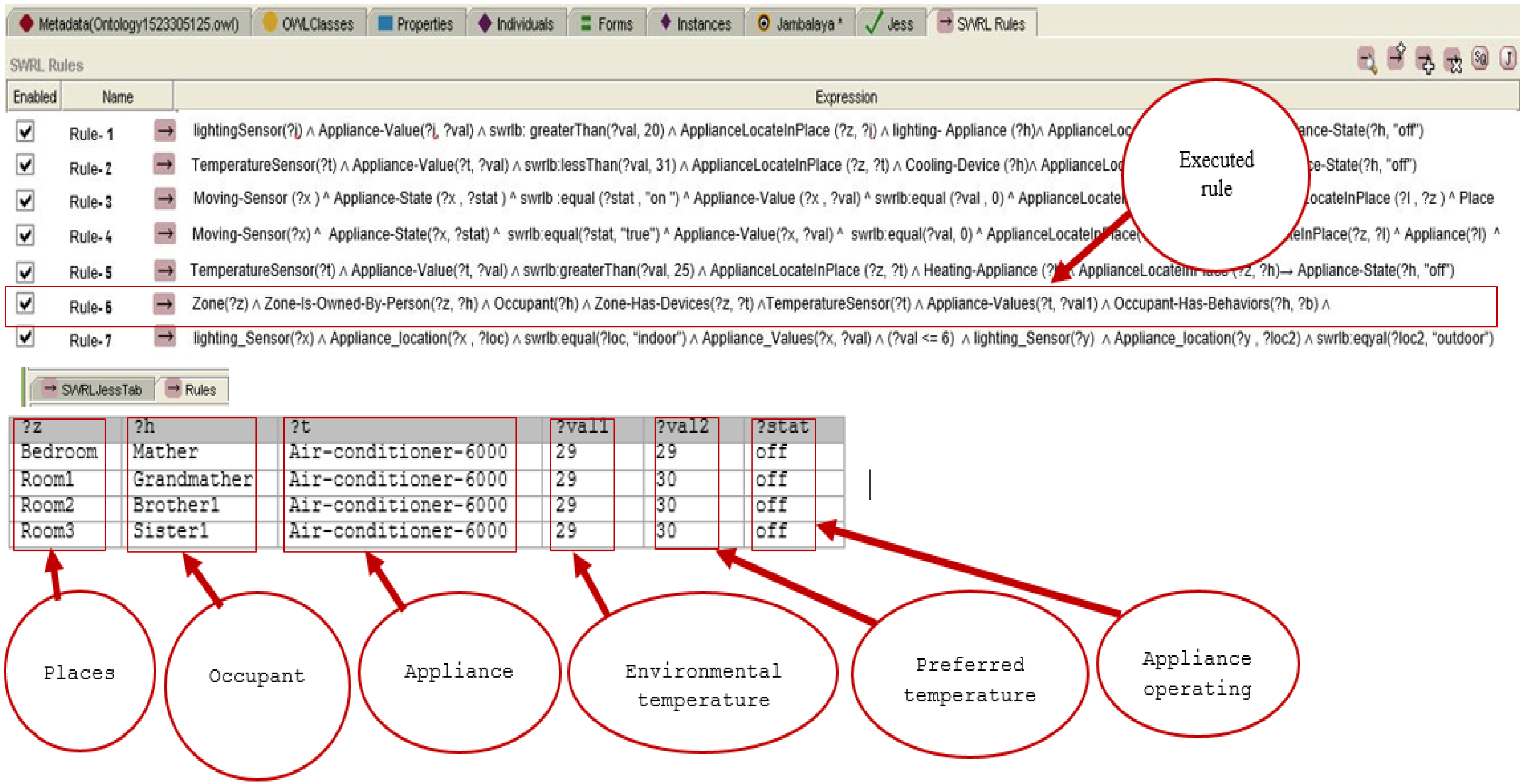

Fig. 10. The cooling devices operating rule according to the occupant wishes

5. ANALYSIS AND DISCUSSION

The energy consumptions obtained by both scenarios (with and without OSEIM intervention) are illustrated in Figure 11. The consumed electrical energy without OSEIM intervention (first scenario) is greater than or equal to the consumed electrical energy with OSEIM intervention (second scenario). However, OSEIM has demonstrated its efficiency in terms of energy savings following its interventions in different cases, including:

- An energy saving of 1633,33 Watt is obtained during the period of 05h:00m:00s at 05h:59m:59s due to OSEIM interventions, exactly "R2" and "R5", for the shutdown of air conditioners if the temperature is less than or equal to 31 °C.
- An energy saving of 1750,00 Watt is obtained during the period of 06h:00m:00s to 06h:59m:59s due to OSEIM interventions, exactly "R2" and "R5", to stop the air conditioners if the temperature is less than or equal to 31 °C.
- An energy saving of 2212,50 Watt is obtained during the period of 07h:00m:00s to 07h:59m:59s due to OSEIM interventions, exactly "R2" and "R5", for the shutdown of air conditioners if the temperature is less than or equal to 31 °C, and the rule intervention" R1" to switch off the lamps in the presence of an acceptable external lighting. In addition, the rule intervention" R7" to the open of house windows if the exterior lighting is accessible.
- An important energy saving is obtained during the period of 07h:00m:00s to 19h:59m:59s due to OSEIM interventions, exactly "R1" and "R7", to open of house windows and switch off the lamps.

On the other hand, we distinguished some situations with difficulties to save energy using the intervention of OSEIM, for example from midnight to five o'clock in the morning, where we note the absence of occupants activities.

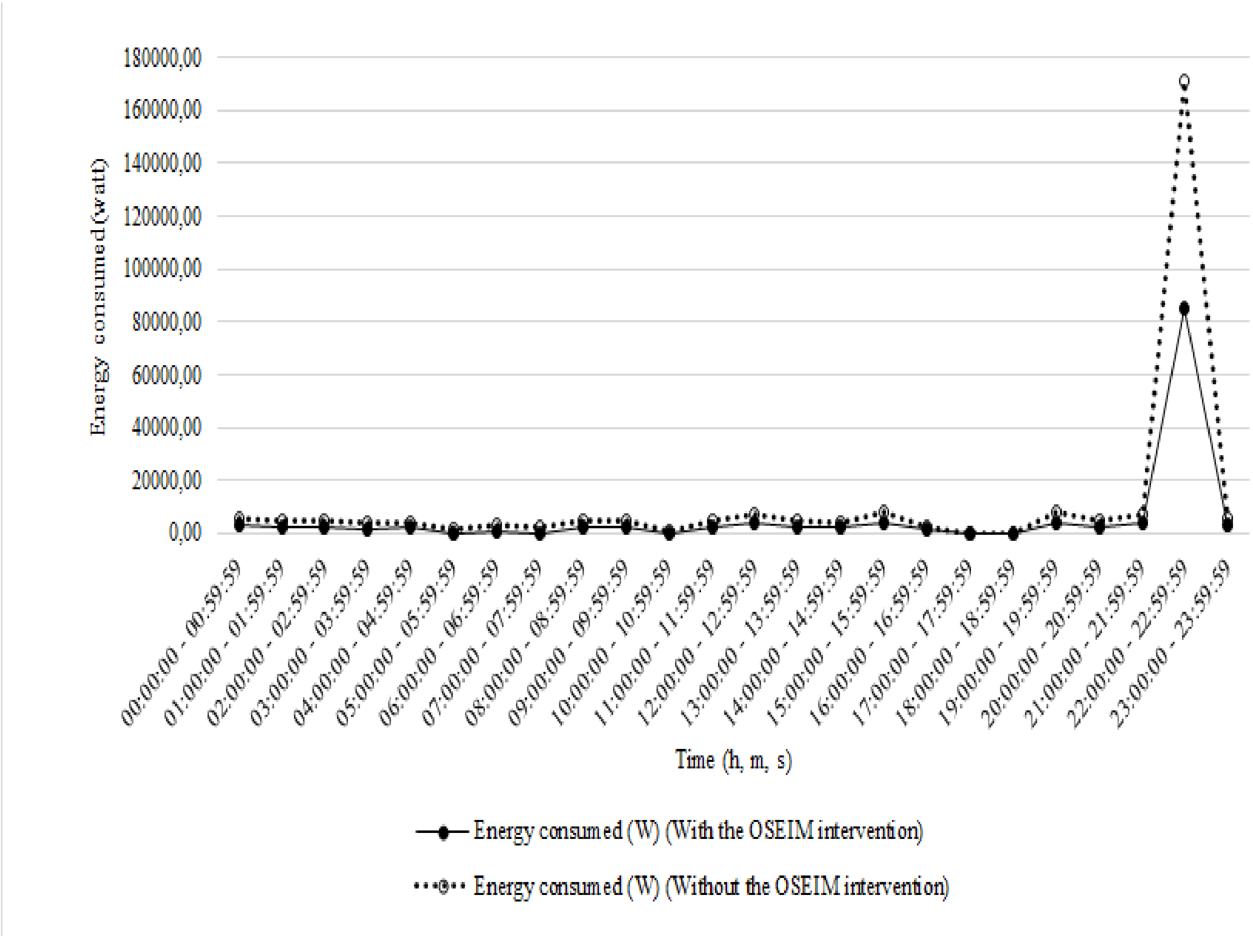

Fig. 11. Energy consumption with and without the OSEIM intervention

6. CONCLUSION AND PERSPECTIVES

A smart home is a high efficiency house that uses the new information and communication technologies (NICT). The goal with a smart home is to improve the energy and electrical appliances management. It will allow transmitting information, to manage and store data on the use of the house to adapt and make profitable the consumption of energy. However, a management system of a smart home optimizes comfort and saves energy by adapting the operation of technical equipment (heating, ventilation, natural and artificial lighting, etc.) to the occupant needs. In this context, we have proposed the present contribution.

From the information viewpoint, a house is an open and distributed system includes a large amount of information, which requires good structuring. For this, we have chosen the ontological approach for OSEIM. The knowledge base of the solution includes information’s on the occupants, electrical appliances and climatic data of Adrar region in Algeria.

To accomplish this work, we followed a steps series. The first step represents a field study of everything related to the studied house. The results of this step are an extract of information include the concepts, attributes of concepts, relationships between concepts, instances associated with concepts and rules of intelligent reasoning. In the second step, all these obtained information are edited using the "Protégé" software and checked using syntax check of the edited information. Finally, the last step represents the implementation of OSEIM using both treatment scenarios (with and without OSEIM intervention). The obtained results show an energy saving of 4.58%.
Furthermore, the proposed OSEIM off and turn on electrical appliances with an acceptable energy management without reducing the comfort desired by the occupants. The proposed OSEIM affords the following management activity:

- Ability to turn off the heating and cooling systems according to the outside temperature and the wishes of the occupant, which allows saving of energy and assure the comfort of the occupants.
- Ability to open and close windows to benefit from sunlight.
- Lamps extinguishing in case of absence of a person in a place of the home.
- Stop of all appliances in the house in case of total absence of occupants.

Exploitation viewpoint, OSEIM is characterized by many advantages, among them:

- Flexibility in its use ;
- The ability to update the knowledge base, without repeating the design stages;
- Adaptation with all the cases (change of home, change of the region, ...);
- It is considered a demonstration platform for students and teachers.

For future work, we have programmed the following tasks:

- It is important to enrich the knowledge base with other information about the occupants, the equipment and the environment of the home ;
- Consider some cases that are not considered in the current solution, such as the operation of the cooling and heating system before the occupants return at the home, for the extreme cold or heat cases, to ensure an acceptable comfort of the occupants;
- The saving of the used energy in the standby-state of several types of equipment, by turning it off to save more energy.
- Integration of renewable energy sources (photovoltaic solar cell, solar cooker, solar water heater...etc.) in the smart home.

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