# NEW APPROACH TO AUTOMATIC AND RELEVANCE DECISION-MAKING IN A SMART HOME BY COMBINING A HIGH-LEVEL CONTEXT-MANAGING ONTOLOGY AND A RULES BASE

**MOHAMED EL HAMDOUNI[1] , YASSER MESMOUDI[2], ABDERRAHIM TAHIRI[3]**

[1]abdelmalek Essaadi University,National Scool Of Applied Sciences Of Tetouan,Morocco
[2] Abdelmalek Essaadi University,National Scool Of Applied Sciences Of Tetouan,Morocco
[3] Abdelmalek Essaadi University,National Scool Of Applied Sciences Of Tetouan,Morocco

E-mail: [1]mhd.elhamdouni@gmail.com, [2]ymesmoudi@uae.ac.ma , [3]t.abderrahimi@uae.ac.ma

**ABSTRACT**

The Smart Home is a residence equipped with computer technology that assists its inhabitants in the various situations of domestic life by trying to optimally manage their comfort and safety by action on the house. The detection of abnormal situations is one of the essential points of a home monitoring system. These situations can be detected by analyzing the primitives generated by the audio processing floors and by the apartment's sensors. We propose in this paper a Inference and decision-making model based on a high-level ontology and rules base.

**Keywords:** *IA, Decision, Ontology, Smart Home, Rules.*

## 1.INTRODUCTION.

A Smart Home is a residence equipped with computer technology that assists its inhabitants in the various situations of domestic life by trying to manage optimally their comfort and safety by action on the house. Detection of Abnormal situations is one of the essential points of a home monitoring

system. These situations can be detected by analyzing the primitives

generated by the audio processing and by the sensors of the apartment.

For example, the detection of screams and dull noises (fall of a heavy object) in a reduced time interval allows to infer the occurrence of a fall.

Some knowledge about the apartment and the inhabitant can be specified

with an ontology. It is a formal representation of knowledge through concepts belonging to a field but also to their relationships; instances of these concepts can also be specified

to make inferences about domain properties.

The main advantages of an ontology are a standard vocabulary for describing the field and the ease of making changes in the content when necessary.

Among the knowledge that can be specified, we can mention for example the location of rooms in the apartment, location of sensors, features of the person (age, impairments, preferences). Ontology can also be used to make an abstraction of information to logical elements that are used for the context recognition.

In this article we will describe a state of the art of pre-exixtant ontologies and we will propose a high-level ontology.

## 2. CONTEXT AND AMBIENT INTELLIGENCE:

McCarthy (1993) presents context as a set of abstract mathematical entities with properties useful for the logical applications of artificial intelligence. However, the term context is used in computer science with a meaning that may vary depending on the field of application. For example, in Natural Language Processing (NLP), the notion of context is different from that used in the field of human-machine interfaces. In addition, it should be noted that not only is there a definition specific to each domain, but it is also possible to find more than one definition of context for the same domain. Nevertheless, we can say that, in any case, context is associated with the interpretation of an entity and its meaning; for example, with regard to the interpretation of a word in NLP, a word can have several meanings, and its interpretation depends on the context (given by the sentence) in which it is located. In the context of ambient intelligence, context was initially limited to specific information such as location (Schilit et al., 1994; Brown et al., 1997). Then, other elements were added such as orientation, user emotional state and date (Dey, 1998). On the other hand, simply defining the context from a list of information is too restrictive because there are circumstances where the elements in play might not belong to this definition. The definition of the concept that seems to us the most relevant in the state of the art is that given by Dey (2001): The context is any information that can be used to characterize the situation of an entity 10. An entity can be a person, place, or object that is considered relevant to the interaction between the user and the application. We find this definition more general and better suited to our research. Indeed, context is always associated with a situation in which it is necessary to reduce ambiguity, and context is not applicable only if a situation is likely to have several interpretations. In addition, the context does not contain all the information available for the system, but only a subset that is useful for disambiguation. The information composing the context is not the same in all cases, it changes when the situation evolves; thus, for example, time could be the most important element of context in one situation and be completely insignificant in another. However, Abowd et al. (1999) and Ryan et al. (1997) have identified as the most important elements in characterizing the situation of an entity: – time, – location, – activity, – and identity of the person. These elements relate to the essential aspects of the context described by Schilit and Theimer (1994): – "Where are you?", – "Who are you with?", – "What resources do you have?". In addition, an app that uses context needs to know when, and what (what the person is doing) to determine why a situation occurred. In this research work, we will use the same elements to compose the context, except the identity of the person which is not important since we assume the presence of a single person in the environment. However, the importance of each element of context will depend on the situation to be assessed.

## 3.RELATED WORK.

The contexts are “used to describe places, agents, and events” Chen et al [1]. Contexts can be classified as external or internal; and physical or logical. Several ontologies have been proposed for context-aware systems to effectively label contextual information collected from sensor devices in the form of sensor data. This section reviews some of the ontologies that pertain to contextual information. We emphasize on specific ontologies as the context in which an application is operating is highly dependent on the domain. A university campus is likely to have a different set of activities than a smart-home environment. Domain-specific ontologies can help create better concepts for semantic labeling of contexts. In IoT applications, it is important to correctly interpret the data from sensors in order to make decisions. In order to semanticize the contexts of IoT applications, Baldauf et al. suggest using machine learning algorithms. [4] propose the common architecture principles of context-aware systems based on the classification of contexts: ex-ternal (physical) or internal (logical). External context is those that can be measured using physical sensors, while internal context is those that are explicitly specified by users or captured by monitoring user interactions (user’s goal or emotional state). The authors provide a conceptual design framework that explains how context-aware architectures work. The context for this situation is the room where the student is sitting. The agents are the student, the professor, and the adviser. The events are the student's question to the professor, the professor's answer, and the adviser's response.[5] Propose COBRA-ONT for smart spaces to help protect people from unexpected events. They describe places using a latitude and longitude with two different types of places, with different constraints. There are other agents, like humans and software, that are located in places and play certain roles to perform some activities. The authors propose a broker architecture that can be used to acquire and reason over contextual information from mobile devices in order to reduce the burden on developers. Since in IoT applications, the concept of a location may vary from appoint to a place of interest, COBRA-ONT is one of the most promising ontologies to represent the location context of "things" (items). The location can be described with a string, and it can also be used as a placeholder for a location. The researchers found that contextual information about a person's location can be correlated with other information about that person, including their ethnicity and other characteristics. I propose an ontology that is based on the information provided by mobile device sensors. Virtual events are events that take place outside of the normal course of events. To provide context-aware services that are more efficient and reliable. The proposed ontology defines the relationships between user location and contexts. The authors propose a reasoner that explains how ontology is related to reality.

*Table:1:Some Ontologies*

| | |
|---|---|
| **COBRA-ONT** | one of the most promising ontologies to represent the location context of "things" |
| **Kim et al** | propose an ontology based on the information provided by mobile device sensor |
| **Okeyo et al** | propose an ontology to semantically label the Activities of Daily Living (ADL) |
| **Lee et al.** | propose UAO (University Activity Ontology) which caters to activities specific to a university campus |
| **Bae et al.** | present RADL (Recognizing Activities of Daily Living) system to classify three different kinds of services in smart-home environments. |
| **CONON** | CONtext Ontology |

## 4. A SMART-HOME DOMAIN ONTOLOGY WITH TWO LEVELS.

The knowledge necessary for intelligent controller operations is organized according to two semantic layers: a low-level ontology and an ontology of
high level. The separation of ontological representations in different levels of abstractions has often been applied in ambient intelligence (Gu et al., 2005; Wolf et al., 2008) in order to make home automation systems more flexible. Segregation between knowledge about inference processes and those representing physical structure environment usefully reduces the impact of configuration changes in the home automation network on inference processes. In addition, it allows to adapt easily the system to other smart homes with different infrastructure, and even in other smart environments, classrooms for example.

In our implementation, the low-level ontology is dedicated to the representation of elements that make up the perceptual environment. At this level, we are interested in everything first to define the regions of physical space, the places and their subdivisions, then the placement of objects in the physical environment. These can be objects that are not not attached to a specific location like windows, or others that are characteristic of a certain location like the refrigerator that is usually in kitchen. This distinction is essential for inferring high-level information (localization and activity) from the evidence on the use of some of these objects. Ontology also describes the devices associated with the objects, it is from the sensors that the controller can detect in some cases the manipulation of an object. The information entered in this ontology includes the type of information provided by the devices, their possible states. and their identifiers. This knowledge does not change during the operation of the system. However, changes in the state of these devices are also stored in In this ontology. The goal is therefore to build a representation physical space that will be used to store low-level temporal data.

High level ontology represents concepts that are used at the reasoning level. These concepts are organized into three parts listed below:

- **Rules entity**. These concepts relate to the elements used in inferences that

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do not relate to physical objects, such as the Situation or Order concepts. In most cases, the instances of these concepts are the possible values resulting from an inference process. So, for example, cooking or sleeping are instances belonging to the Activity class.

- **Physical entity.** This groups together the classes that designate physical objects that are found in physical space or existing rooms. Unlike ontology low-level, here we do not try to describe specific objects in the environment, but rather to list the existing objects in the apartment without being interested in
specific properties such as their location or identifiers. For example, a
instance of the Object class is simply a door , without specifying which real object in the space she refers to.

- **Event entity** . The instances in the high-level ontology are produced by the inference modules (e.g. location, activity, and situation) after processing the information from the sensors (which have been previously stored in the ontology of
low level). These instances correspond to the realization of abstract entities,
such as carrying out an activity in a location and at a specific time (for
example, at 1:00 p.m. the inhabitant takes his meal in the kitchen).

## 5.THE HIGH LEVEL ONTOLOGY,MODEL PROPOSED AND SOFTWARE IMPLEMENTATION :

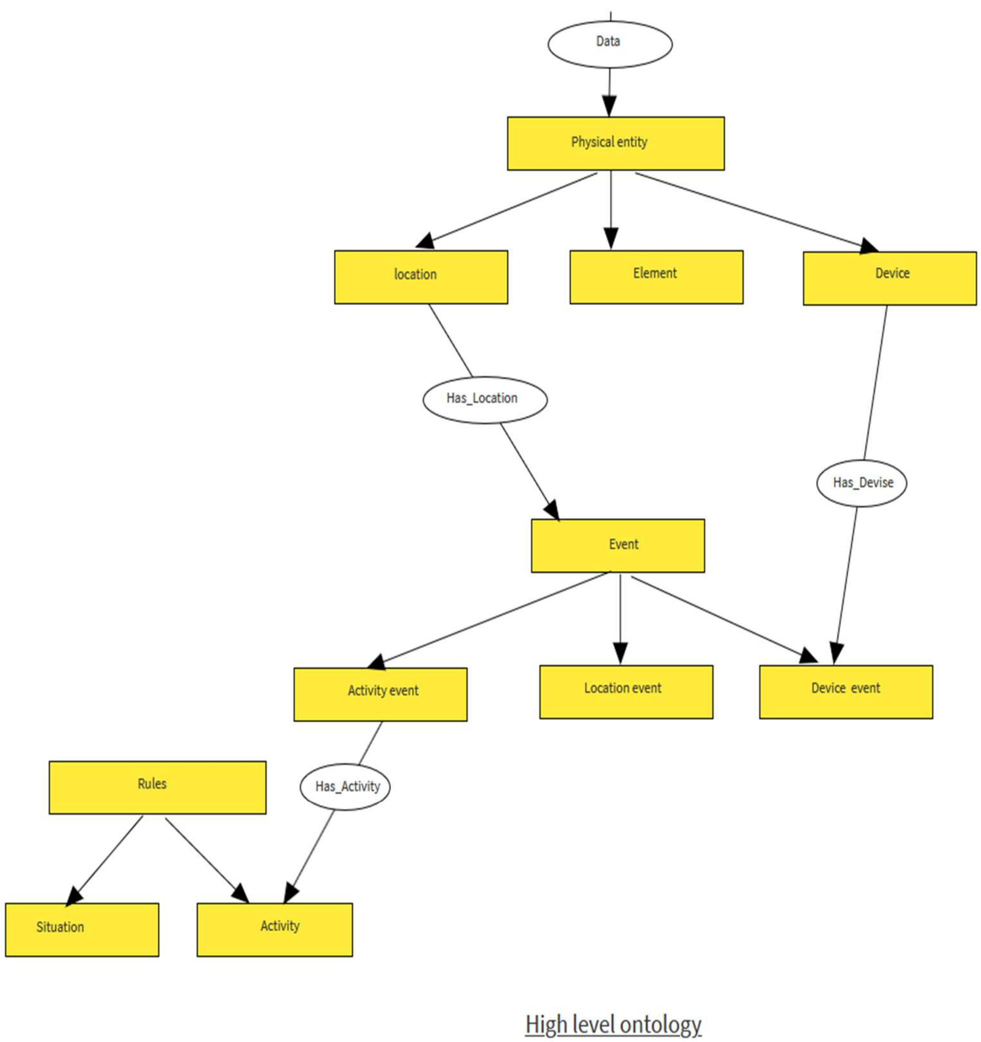


*Figure:1: High Level Ontology*

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An ontology is defined as an explicit specification of a conceptualization (Gruber, 1993). Ontologies formally represent knowledge as a set of concepts and their relationship in a field. They are experiencing a significant boom in

derable with the development of the semantic web. Generally speaking, the ontology They are often used in computer applications to formally define the data exchanged in order to facilitate the transmission of data between services and to enable put high-level queries. Its development within intelligent systems is due not only to its ability to represent but also to the medium it offers

the functions of communication, reuse and reasoning. In our research, we

we are interested in ontologies formalized by the Ontology Web Language (OWL) (Dean and Schreiber, 2004), which defines a language for specifying ontologies based on the Description Logic (DL). Description logic (Baader et al.,

2008) is a type of logic used to describe concepts and their roles (relationships). It is based on the logic of the first order with the idea of formalizing semantic networks. Ticks. However, its language deviates from the logic of the first order. Indeed the main motivation is to obtain a sufficient language for the modeling tasks and for have good decidability, consistency and satisfyability properties. The principle of The difference between description logic and logic programming (e.g. Prolog) is the open-world assumption that one cannot affirm or deny the truth of a clause if it is not explicitly defined or if it cannot be deduced directly of the present knowledge. In logical programming, on the other hand, If it is not possible to prove the truth of a clause, it is considered false. One of the main objectives of OWL is to facilitate the integration of reasoning capabilities in descriptive logics into the semantic web. Three types of OWL were challenged. Nis. OWL Lite is the most basic of the OWL languages and can be used to express simple taxonomies and restrictions. OWL DL supports more expressiveness while ensuringant completeness and decidability for reasoning. OWL Full has no restrictions expressiveness, on the other hand completeness and decidability are not assured.

The reasoning consists in deriving facts that have not been explicitly expressed.

in ontology. The reasoning tasks for an ontology are mainly the

Following:

– **Satisfiability:** Determining whether the definition of a concept is not contradictory is to say whether there can be an individual who is an instance of the concept.

– **Subsumption:** Determine whether a concept C subsumes a concept D.

– **Consistency:** Determine if individuals do not violate descriptions and axioms

that describe the concepts.

– **Equivalence:** If the definition of a concept C is equal to that of a concept D.

– **Disjunction:** If the set of individuals of a concept C is disjoint from that of the concept

D.

Creating an ontology involves understanding the field of knowledge.

This process is often implemented with the help of an expert in the field. Two factors are to be considered when creating an ontology: the final objective (representation, reasoning, applications that will exploit knowledge) and the extent of the coverage of the domain in order to include only the relevant elements. In the state of the art of the Ambient intelligence systems, all ontologies used in applications have were built by expertise. Yet, there are methods for machine or semi-automatic learning of ontologies (Hazman et al., 2011). However, most of these methods make it possible to extract ontologies from texts.As with systems based on logical rules, the language for describing ontologies is very expressive. Even if reasoning skills are more important.

iterated than those of logical programming systems, the advantage of management interfaces of ontologies is to include not only a mechanism of inference of new knowledge-Sances but also a representation platform that allows reuse and sharing knowledge between the different components of a system. But as with logical systems, this description has its limits and in particular this approach cannot deal with uncertainty. Despite this, when high-level information is not affected by uncertainty, reasoning by the mechanisms embedded in ontologies is very interesting because it is done directly in the knowledge model and the update of the descriptions in the ontology is made automatically. The coupling of knowledge declarative and the reasoning is very strong.

In everyday life, we use context to make decisions. It is sometimes the center of our conversation and manifests itself implicitly or explicit. Context data is therefore crucial for understanding of the situation in which we find ourselves.

A poor understanding of the context can have serious consequences. Consider the home assistance scenario for an elderly person with Alzheimer's disease. If it enters a room, then turn on the light in this room, then when there are no more movements in the room turn off this light. It is clear that this scenario does not work, because several contextual information are not taken into account during the execution of the scenario. We know that Elderly people make very little movement and are sometimes with reduced mobility so they can watch TV, lie on the couch or stand still for a while minutes without doing anything. We see here that no information on the what and how of the person, has not been taken into account and at the risk of turning off the light to bad escient.

As A. Dey says, the use of context is important in interactive applications and even more important for applications in which the user's context changes rapidly. The definition provided by Schilit and al for the notion of context highlights three important aspects: where is the no one; who is with the person; and which resources are close to the No one? This definition implies constant monitoring of the environment in which the person evolves with a person-centered approach.

Below is the model that we have proposed based on the high-level ontology developed previously in this article:

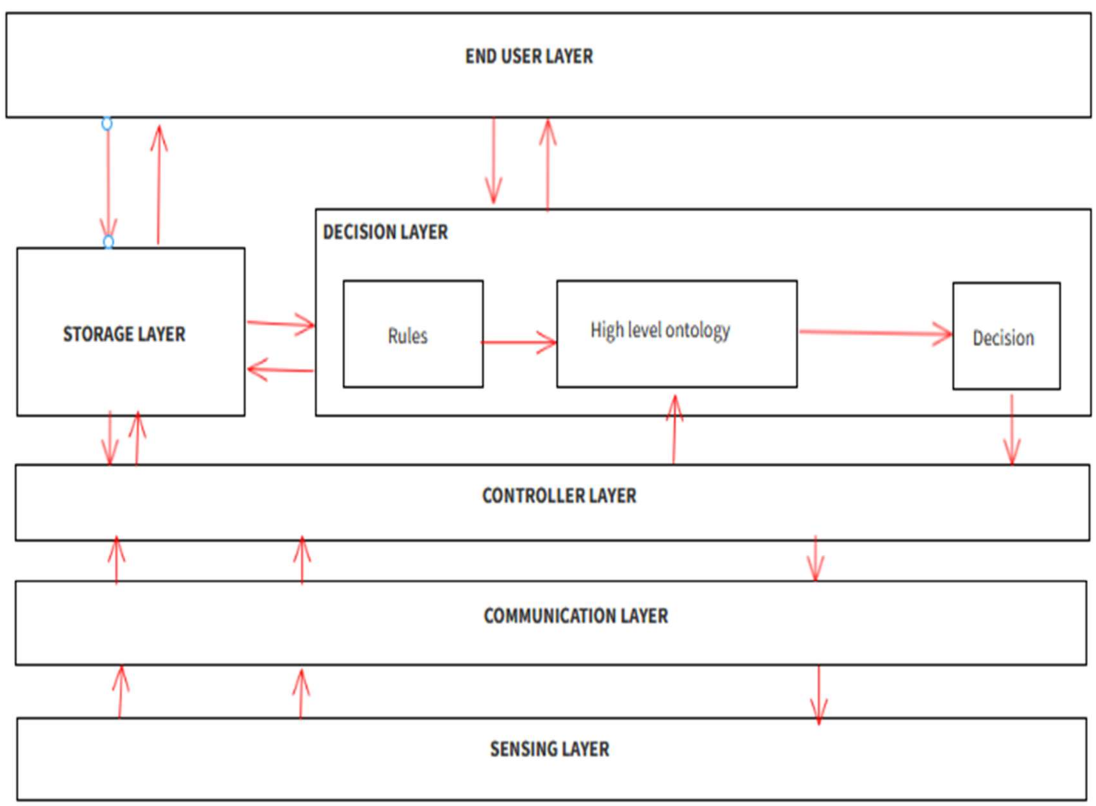


*Figure :2: Proposed model*

**Rules:**

In the process of context inference and decision-making, it is important to be able to include explicit knowledge beyond the knowledge learned by automatic prentissage. For example, logical rules to describe that if the person is a few minutes in the kitchen and in the meantime she has turned on the oven and opened the fridge, so the current activity is "cooking". If a programming method

Statistical logic is applied, such a basis may have a numerical weight associated with each rule to model uncertainty. Then this value represents the probability that a rule be true in the real world.

The rules in this module are mainly used to specify situations of interest and actions which must be executed when they are recognized.

**Decision:**

This component takes as input the output of the ontology to decide whether or not to act, and whether to take action. Eventually this will result in the next module sending commands to the controller layer in link with the things in the apartment: turn on the light, turn off the oven, make a call emergency.

Ambient assistance systems that do not use ontologies are, for the

most, based on rules to provide the necessary intelligence for the habitat. Concrè- These systems use first-order predicate logic to find

the constraint to satisfy. Each constraint in the form of a scheduled program (script) listens to the input-output, retrieves the value or the posted data and then propagates it to all of its rules to verify those that will be satisfied.

To fully understand this, let's take the following example again. In this example, the smart home wants to illuminate the hallway when the elderly person gets up during the night. If the sensor of movement of the bedroom indicates "ON" it triggers the ruler to turn on the lights of the room as soon as a movement in the room is detected. This rule to be efficient adds temporal information so that run only after 6 p.m. Despite this, this rule remains very ineffective, in the sense that it does not know anything about the context in which it runs. No knowledge of the sensor history is known about the rule system, resulting in disability to establish very precise rules. In addition, no information is given on

interactions between existing rules. Do they conflict? Do they cancel each other out? The lack of information on other entities involved in the process does not does not make this rule robust or manage temporal information, and

Space.

An example of information used in a smart home is the value of the state.

a bedroom motion sensor. The value of the "ON" data only makes sense if we associate it with the device and the place in which it was captured. This

information is then represented and then encapsulated with other information such as the time and merged to give birth to a knowledge. Example: The sensor Movement of the room above the bed gives "ON" at 22 hours 25 minutes.

This knowledge is associated with another knowledge: every evening at 8 p.m. on no one lies on their bed to fall asleep. Inference allows us on the basis

of this knowledge to say that the person is on his bed probably in the process of sleep.

To enable the specification of knowledge, its expression, representation and sharing between machine or human and any other entity, the W3C (World

Wide Web Consortium) has implemented a graph-oriented formalism based on XML standards.

**A high level ontology scenario:**

It is 9 pm, the resident is getting ready to go to bed. She goes in her bed and reads a book. After 20 minutes, the system tells him that the front door is not locked. She thinks she will do it later then 5 minutes later she turn off the light. the system tells him that the front door is not locked. She asks for the light, go lock the door, go back to the room, turn off light and fall sleep.

when the inhabitant turns off the bedside lamp before sleeping. The controller updates the status of the devices in the low-level ontology, and it can be inferred — still at the low level — that all the lights in the room are off. In high-level ontology, interaction with the lamp is stored as a device

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event having the time of occurrence and the part as properties. Then the localization module is used and the result of the location is directly the room since the switch is in this room. Evidence on the location of the inhabitant, the state of the lights, and the period of the day, may be enough to infer that the common activity is sleeping. Finally, these inferences provide the context on which the situation recognition is made. In the same scenario, if the person forgets to close the main door and if a situation has been defined for this case, this situation will be labeled in the ontology as recognized and then processed by the decision module. Situation recognition through reasoning with ontologies.

In addition to the representation of knowledge, ontologies also offer the possibility of inferring knowledge through logical reasoning. We use this capability to analyze the state of the environment at a certain moment relative to a set of instances. In the low-level ontology, the LightsBedroom concept gathers all the lights that are in the room, so that the LightsBedroomOff subconception refers to the subset of lights off. Those groups are very useful for situation definitions. For example, to define a situation in which all the lights in the room are turned off, for example when the no one sleeps at night, it is not necessary to assess the state of all the lights, but it Just evaluate whether or not there are instances in the LightsBedroomOn class.

**Software implementation:**

The controller has been implemented entirely in the Java language. The use of a language object-oriented programming is very relevant in our research because of the modularity that the implementation of the controller requires and also the ease of adding optional components. All classes use the Singleton design pattern to restrict their instantiation to a single object that remains in memory throughout the execution of the system. In fact, the entire processing chain is coordinated with only one instance of each class when an event arrives, so there is no not a time t in which more than one instance is needed. This model improves the performance of the system since it requires less memory than the generation of instances in each event. The OWLAPI library was used to manipulate ontologies whose language is OWL2. The second component external integrated in the controller is the Carados library used to consult the information stored in the ontology in an efficient way.

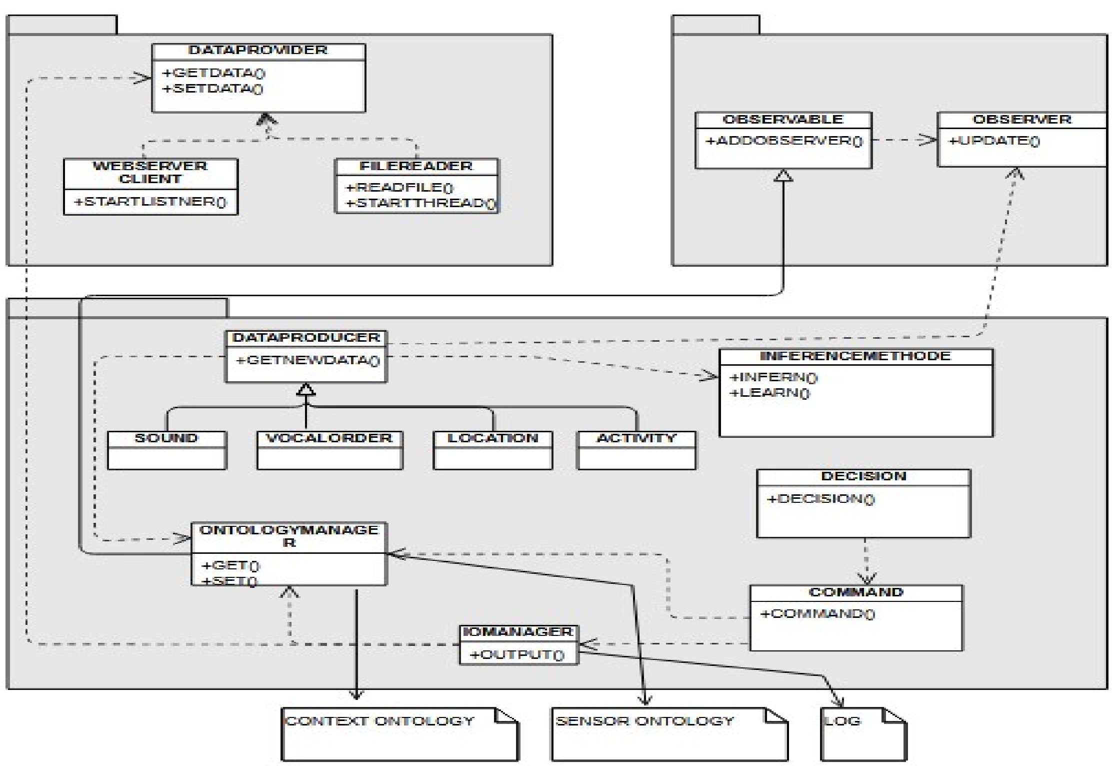


*Figure3 The Class Diagram*

Figure 3 shows the class diagram and package organization of the controller. The first package contains the classes that allow the connection with the sources information and actuators. The main package groups the classes that implement lie knowledge base access and inference methods. Finally, the software relies on a package for design patterns whose main one is the observer . Hierarchical information inference is implemented at through this pattern. Thus, the classes in charge of inferring high-level information are observers and successor classes in the hierarchy are observer objects.

## 6. EVENT-CONDITION-ACTION : SEMANTIC IMPLEMENTATION (ECA) :

The interest of the recognition of situations in our research is rather the definition event-condition-action (ECA) rules that are easy to include in the knowledge base and that serve to express the reactive behavior of the controller. In this case, we do not deal with information uncertainty. Two situations to recognize were implemented in the experimental scenario. The description of these situations with their representations by SWRL are shown below:

1. Situation 1. Event: The person opens the main door of the apartment to go out. Condition: the bedroom windows are open. Action: Send a message through the voice synthesizer.

**Representation by SWRL**

*DeviceEvent( ?d), has_associated_object( ?d, door),*
*takes_place_in( ?d, kitchen),state_value( ?d, open),*
*Window( ?w), located_in( ?w, bedroom),Application( ?a),*
*has_application( ?w, ?a),curret_state( ?a,on)*
*→ current_state(BedroomWindowsOpen, detected)*

2. Situation 2. Event: The bedroom lights go out. Condition: the curtains and the windows are closed, and the main door is open. Action: Send a message through the voice synthesizer.

**Representation by SWRL**

*DeviceEvent( ?l), has_associated_object( ?l, light),*
*takes_place_in( ?l, bedroom),state_value( ?d, off),*
*Window( ?w), located_in( ?w, bedroom),Application( ?a1),*
*has_application( ?w, ?a1),curret_state( ?a1,off)*
*Blind( ?b), located_in( ?b, bedroom),Application( ?a2),*
*has_application( ?b, ?a2),curret_state( ?a2,off)*
*Door( ?d), located_in( ?d, kitchen),Application( ?a3),*
*has_application( ?bd, ?a3),curret_state( ?a3,on)*
*→ current_state(MainDoorOpen, detected)*

## 7. CONCLUSION

The complete definition of ontology and the division of the representation model into two semantic layers is a particularly useful approach to adapt the system to new intelligent environments. Knowledge is not limited to describing the physical elements in the smart home; but they also contain abstract elements and the existing relationships between the different concepts of the domain. The extension of the knowledge model through the inclusion of logical rules has shown its relevance for the representation of situations at risk or distress.

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