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Saving the lives of people in need with smart early warnings based on Semantic IoT.

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The thank

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Dedications

To **my parents** that I owe them all the gratitude and recognition because without them I would never have arrived here.

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To all those I love and those who love me.

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Abstract

The digitization of the physical world has received considerable attention and, thanks to advances in technology and connectivity, any object can now be connected to Internet. Different technologies and software are becoming interconnected, communicating without direct human intervention within the Internet infrastructure. This phenomenon is collectively referred to as the Internet of Things (IoT). It has become a widespread phenomenon in all spheres of life.

In general, the main objective of the project is to provide a smart technological solution that helps the health and social services sector to anticipate critical cases of people in need before they arise, so that they can intervene in timely. By developing a network infrastructure of semantic connected objects that can securely manage the massive flow of data, while being simple to control and make it work.

Much more specifically, the project will deal with the subject of the use of IoT and the semantic web in health prediction. Indeed, IoT technologies cannot prevent danger from occurring, but can be very useful for disaster preparedness.

Take for example heart attacks resulting from the deterioration of the work of the heart and arteries, sensors that a person can wear can take measures that indicate when a hazard has arisen or there is a high risk, e.g. high blood pressure, difficulty in breathing, etc. If there is a critical combination of these parameters, early warning systems based on semantic reasoning alert the sectors concerned and ask for help. The firefighters, when they arrive, have detailed information about the person in need.

Key words: Internet of Things (IoT), Semantic Web, Ontologies, SWRL, Interoperability, Semantic Web of Things (SWoT), Elderly people.

Rèsumè

La numérisation du monde physique a reçu une attention considérable ET, grâce aux progrès de la technologie et de la connectivité, n'importe quel objet, peut désormais être connecté à Internet. Différentes technologies et différents logiciels deviennent interconnectés, communiquant sans intervention humaine directe au sein de l'infrastructure Internet. Ce phénomène est appelé collectivement Internet des objets (IoT). IL est devenu un phénomène répandu dans toutes les sphères de la vie.

En générale, l'objectif principal du projet est de fournir une solution technologique intelligente qui aide le secteur de la santé et les affaires sociales à anticiper les cas critiques de Personnes en besoins avant qu'ils ne surviennent, afin qu'ils puissent intervenir en temps Opportune. En développant une infrastructure de réseau des objets connectés sémantiques qui Puisse gérer en toute sécurité le flux de données massif, tout en étant simple à contrôler et à faire fonctionner.

Beaucoup plus précisément, le projet va traiter le sujet de l'utilisation de l'IoT et le web Sémantique dans la prédiction de santé. En effet, les technologies IoT ne peuvent pas Empêcher le danger à se produire, mais peuvent être très utiles pour la préparation aux Catastrophes.

Prenons par exemple les crises cardiaques résultant de la détérioration du travail du cœur et Des artères, des capteurs qu'une personne peut porter peuvent prendre des mesures qui Indiquent quand un danger s'est déclaré ou qu'il y a un risque élevé, par ex. pression artérielle Élevée, difficulté à respirer, etc. S'il existe une combinaison critique de ces paramètres, les Systèmes d'alerte précoce basant sur des raisonnements sémantiques alertent les secteurs Concernés et demandent de l'aide. Les pompiers, à leur arrivée, disposent d'informations Détaillées sur la personne en besoin.

Mots-clès: Internet des Objests (IdO), Web Sèmantique, Ontologies, SWRL, Interopèrabilitè, Web Sèmantique des Objets, Personnes agèe.

General Introduction

The whole world is a small village where people can keep in touch with others wherever they are and any real object has become a connected being thanks to and via the Internet, this phenomenon is called Internet of Things (IoT) making it possible to make the objects, the places... which surround us intelligent.

The information collected comes from various sources and therefore heterogeneous. What requires the introduction of the semantic web to the IoT so that the different heterogeneous systems can operate in common and therefore guarantee what is called Interoperability between the different information collected as well as the different connected objects, We are therefore talking about the Semantic Web of Things (SWoT) or Semantic IoT (SIoT) approach which is a combination of the Internet of Things and the Semantic Web.

It is on the latter that this end-of-study project will be based, by designing a system that aims to help and facilitate the lives of the elderly and even those who are in situation of need. Because of the difficulties and health problems that they can face, which can seriously affect their daily activities and their lives by giving them the necessary help and follow-up by the relevant authorities through smart recommendations and alerts in the right time:

- ✓ Ontologies allowing to model knowledge in a specific domain, in this work the domain is indeed the medical domain (their vital signs, the obstacles they can find, etc.).
- ✓ Rules based on the SWRL inference engine allowing to enrich the knowledge base thanks to the new knowledge obtained by these rules.
- ✓ Based on the new knowledge, Smart recommendations and alerts will be provided in order to help these people in need in the right time to avoid any danger.

This thesis is organized from the following way:

- **Chapter 1: "State of the art and related work" :** This chapter is devoted to a bibliographical study while presenting the bases of each of the disciplines cited below:
  - ✓ Internet of Things
  - ✓ Semantic Web
  - ✓ Semantic Web of Things

  It is also devoted to related works that have already existed before.

- **Chapter 2: "Design":** As its name suggests, this chapter focuses on the design of the system that we will propose in this project based on the Semantic Web of Things approach while presenting the architecture of the proposed system and all the elements necessary for its completion.

- **Chapter 3: "The implementation":** The realization and Implementation of the system on protègè-2000 will be the subject of this last chapter, also the tools which are used are defined.

Chapter 1: State of the art and related work

1. Introduction

Nowadays, technology has become ubiquitous throughout the world because of what it can bring to the daily life of people in normal situations and also the elderly people. In this context, we will talk about the elderly people and the difficulties encountered by these people in their daily life. Next, we will put the light on the concept "Semantic Web of Things" contributing to facilitate their lives on a technical side. The latter combines two concepts which are: the Internet of Things and the Semantic Web, with the aim of guaranteeing interoperability, citing their definitions, their architectures, their basic concepts and their fields of application.

2. Elderly people

2.1. Definition of elderly people

Through (Orimo et al, 2006), elderly has been defined as a : "*Chronological age of 65 years old or older, while those from 65 through 74 years old are referred to as "early elderly" and those over 75 years old as "late elderly* " .

Through the World Health Organization, the proportion of individuals aged 60 years and older within the population is increasing. In 2019, the proportion of individuals aged 60 years and older was 1 billion. This number can increase to 1.4 billion by 2030 and a 2.1 billion by 2050 [1].

2.2. The problems / difficulties encountered by the elderly people

The main problems/difficulties experienced by the elderly people are:

- ✓ Difficulty in performing daily tasks such as: clothing, hygiene, food, home activities, etc.
- ✓ Difficulty speaking and communicating with others.
- ✓ Difficulty moving from one place to another (during the walk for example).
- ✓ Memory and forgetfulness problems (forgetting medication times, for example).
- ✓ Psychological problems due to a feeling of helplessness.

Figure 1.1: Elderly people problems [2].

2.3. Problem resolution:

With the emergence and development of the technology and the Internet rapidly, we can handle with the difficulties and the problems mentioned above from a technical point of view helping to solve them as well as facilitating the lives of elderly people, And this is what will be presented in the following sections by taking the two concepts: Internet of Things and Semantic Web as technical solutions to help the elderly people and facilitate their daily life in a better conditions.

3. Internet of Things (IoT)

In this section, we present the concept of the Internet of Things (IoT) starting with its different definitions.

3.1. Definition of IoT

In fact there are several definitions of the Internet of things technology, In this section we will highlight some of them: Through (H et al, 2015) Internet of Things (IoT) can be defined as: « the ability to make everything around us starting from (i.e. Machine, Devices, Mobile phone and Cars) even (Cities and Roads) are expected to be connected to the Internet with an intelligent behavior and taking into account the existence of the kind of autonomy and privacy » [H et al., 2015].

Other definition given by (Madakam et al, 2015) is as follows: " *an open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment* " [Madakam et al. ,2015].

The Cluster of European Research Projects on the Internet of Things CERP-IoT defines it as: " *a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network* " [Sundmaeker et al. ,2010].

Simply, Internet of things can be defined as: a set of objects communicating with each other or connected via the Internet in such a network.

This vision of the Internet of Things will introduce a new dimension to information and communication technologies: in addition to the two temporal and spatial dimensions that allow people to connect from anywhere at any time, we will have a new "object" dimension that will allow them to connect to any object.

The Internet of Things has introduced a new dimension to information and communication technologies in addition to the two existing dimensions which are: temporal and spatial dimensions that allow users to connect at anytime from anywhere. The new dimension which is "object" dimension allows the users to connect to any object [Challal, 2013], as shown in the figure below:

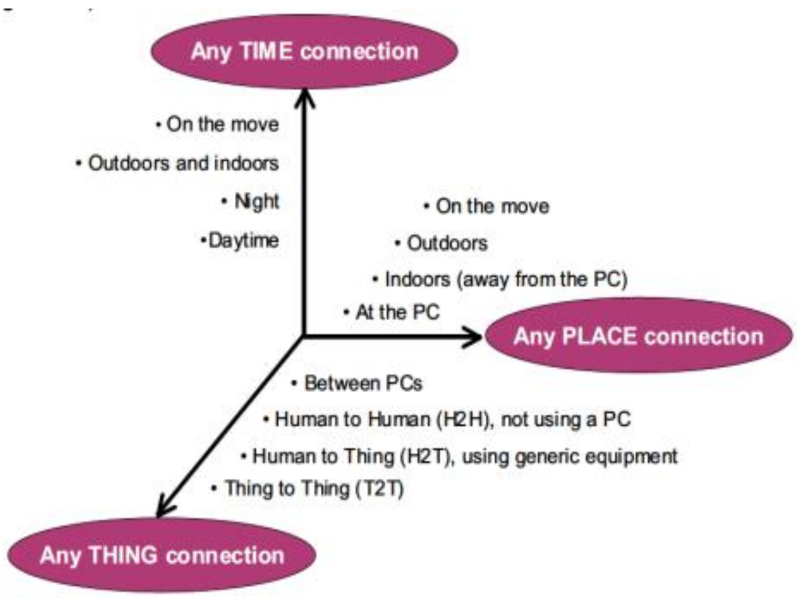

Figure 1.2: IoT's dimensions (Adapted from [Challal, 2013].)

3.2. Characteristics of the IoT

There are the following characteristics of IoT. Let's discuss them one by one:

- ✓ **The connectivity:** Connectivity is one of the important requirements of the IoT infrastructure. All the IoT objects must be connected to the IoT infrastructure. Anyone, anywhere and anytime, connectivity must be guaranteed at all times without a connection, nothing makes sense.
- ✓ **Intelligence and identity:** The extraction of knowledge from the data generated and captured is very important. For example, a sensor generates and captures data, but that data will only be useful if interpreted correctly. Each IoT device has a unique identity. This identification is useful for tracking equipment and sometimes for querying its status [3].
- ✓ **Scalability:** The number of items connected to the IoT zone is increasing day by day. Therefore, an IoT setup should be able to treat the massive expansion. The data generated as a result is huge and needs to be treated appropriately [3].

- ✓ **Dynamic and self-adaptive (complexity):** IoT devices must dynamically adapt to changing contexts and scenarios, for example, a camera intended for surveillance must be adaptable to work in different conditions and different lighting situations (morning, afternoon, night) [3].

- ✓ **The architecture:** IoT architecture cannot be homogeneous in nature. It should be hybrid. The IoT does not belong to any branch of engineering. The IoT is a reality when several domains meet [3].

- ✓ **The Security:** Being connected to the internet may put the users' sensitive data in a risk for being compromised which may cause loss to the users. Therefore, data security is the major challenge, IoT networks can also be at risk. Therefore, the safety of the equipment is also critical [3].

3.3. The Steps followed by the IoT

To have a complete IoT system, it should pass through four distinct steps and components which are: sensors/devices, connectivity, data processing, and a user interface. Below we will briefly discuss each component and what it does:

- ✓ **Sensors/ Devices:** as a first step, sensors or devices collect data from their environment. For example it could be a simple temperature reading or a full video fee. We use generally the term “sensors/devices,” because multiple sensors can be part of a device that does more than just sense things. For example, if we take a phone we can say that it is a device that has multiple sensors (camera, accelerometer, GPS, etc.) so it is not just a sensor [4].
- ✓ **Connectivity:** After the sensing step, the data is sent to the cloud but it needs a way to get there. The sensors/devices can be connected to the cloud through a variety of methods including: cellular, WiFi, Sattelite, Bluetooth, low-power wide-area networks (LPWAN), or connecting directly to the internet via ethernet [4].
- ✓ **Data Processing:** One of the important steps that makes an IoT system works correctly is the data processing. So once the data gets to the cloud, the software performs kind of processing on it. It could be a simple, such as checking that the captured temperature is within an acceptable range or not. Or it could be very complex, such as using computer vision on video to identify objects (such as intruders in your house).

  After this step what could happens when the temperature is too high or if there is an intruder in your house, that’s where the user comes in [4].

- ✓ **User Interface:** Finally, the information is made useful to the end-user after their processing. Based on a good data analysis and processing, the user could receive alerts through (email, text, notification, etc.). For example, the user can receive a warning when the temperature is too high [4].

3.4. IoT's paradigms (Visions)

There are three important paradigms (visions) for the realization of IoT domains [Vishwakarma et al. 2019] which are:

- ✓ **Things- oriented vision:** this vision includes sensors and smart objects, in order to distinguish between the objects, each one is given a differentiated coding.
- ✓ **Internet- oriented vision:** includes internet services as the main focus while the data are contributed by objects.
- ✓ **Semantic- oriented vision:** described by knowledge, and this vision includes a way of storing and retrieving the data from a server.

IoT paradigm exists because of the convergence of different visions, as shown in the figure bellow:

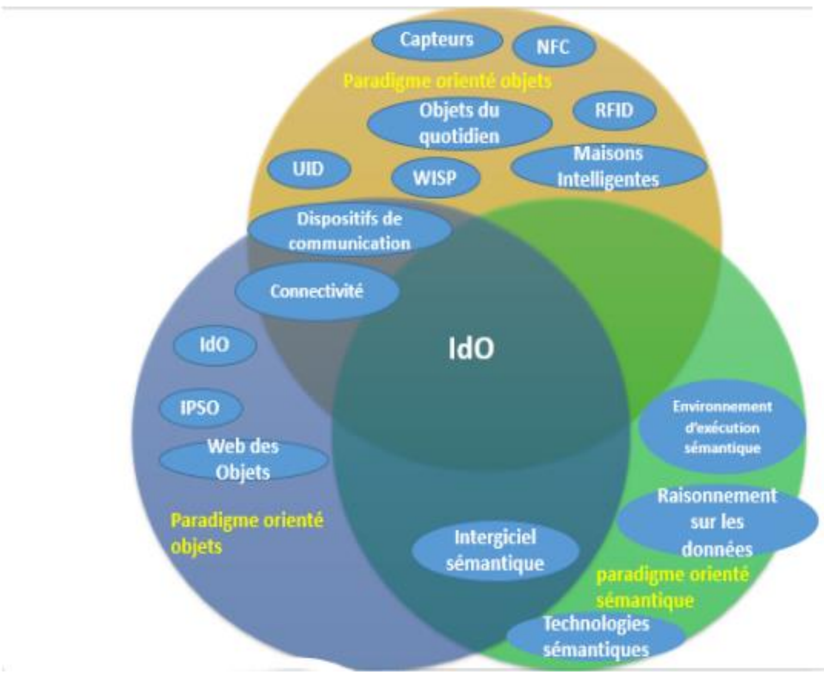

Figure 1.3: Internet of Things paradigms (Adapted from [Vishwakarma et al. 2019]).

3.5. The architecture of the IoT

In order to standardize the design of the IoT systems, it was necessary to have a common reference architecture. As it is shown in the figure below:

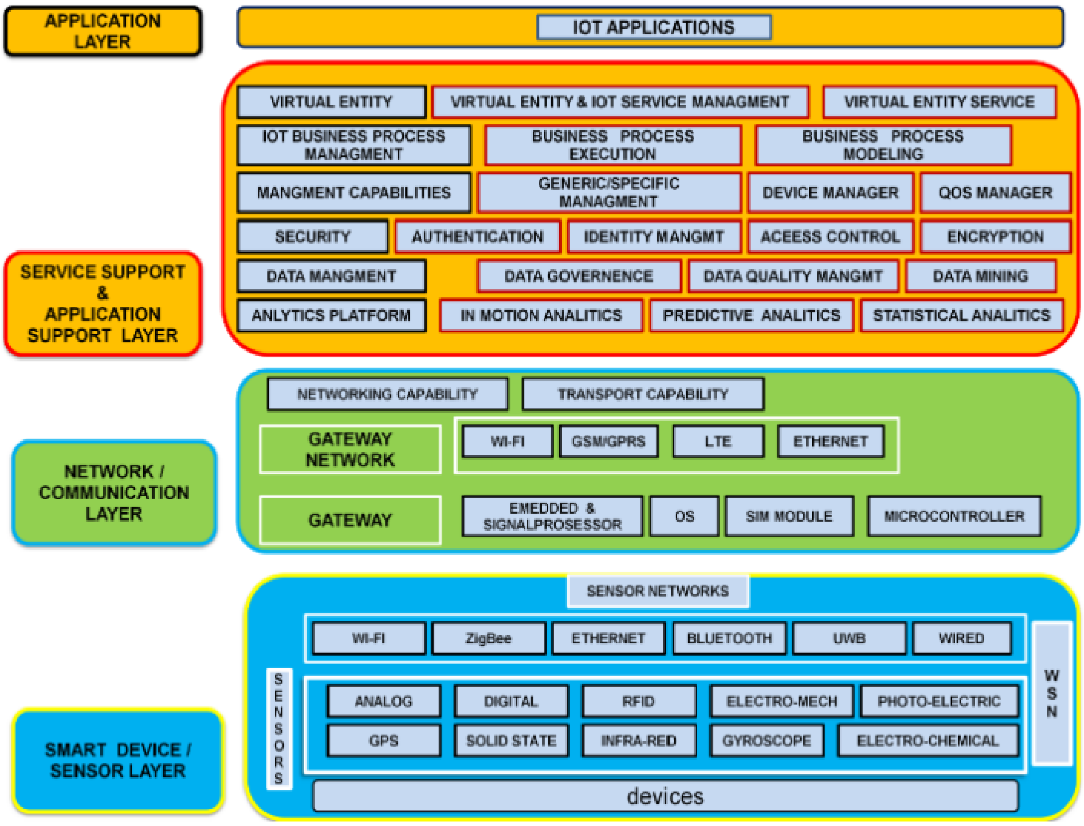

Figure 1.4: IoT’s architecture (Adapted from [Patel et al. 2016])

The layers shown in the above figure are described briefly below:

- ✓ **Smart Device/ Sensor layer:** This layer includes smart objects that are integrated with sensors to interconnect the physical world to the digital one, in order to guarantee the collection and processing of information in real time. There are several types of sensors that are used for different uses such as: environmental sensors that are dedicated to take measurements such as: temperature, air quality, speed, humidity, pressure, electricity, etc. also body sensors, home appliance sensors and vehicle telematics sensors, etc.
- ✓ **Network/ Communication layer:** The huge volumes of data produced and captured by these sensors require a robust and high-performance wired or wireless network infrastructure as a transport medium.

- ✓ **Service/application support layer:** The management service is responsible of analysis, security controls, modeling of process and device management which makes information and data processing possible. Data management can be defined as the ability to manage the information flow of data. With data management in the management services layer, information can be accessed, integrated and controlled.

- ✓ **Application layer:** The application of the IoT covers intelligent spaces in various fields which will be mentioned and explained in the following section [Patel et al. 2016].

3.6. IoT application areas

The application areas of the IoT are shown in the figure below:

Figure 1.5: IoT's Application Areas (Adapted from [Singh, 2018])

Now we will discuss in more detail the main application areas of the IoT:

3.6.1. Smart Home:

"Smart Home" or an intelligent house or home automation is a set of techniques for controlling electrical appliances used in homes (lighting, heating, audio-visual, household appliances, etc.), to automate and program the habitat.

It is a recent new concept increasingly used, it comes from the application of computer programming to the home, taking advantage of computer technologies, telecommunications, and electronics. All these techniques and systems must be interoperable for optimal management. The role of home automation is to provide security functions, energy management, equipment control (alarm, access control, temperature, lighting, fire, etc.) and communications, and in particular comfort, especially for the elderly and the disabled.

The IoT allows us to collect and analyze data from these people in order to diagnose illnesses, assess potential risks, identify and prevent accidents such as falls, if possible, and let member's family monitor them from a distance. Therefore, it is also possible to bring older people and people with disabilities closer to the outside world and to break the feelings of loneliness and isolation in these people as well as to rebuild a connection with the outside world.

3.6.2. Health care:

The IoT makes it possible to remotely manage health and emergency notification systems. Among the most popular approaches is the use of wearable technologies.

These devices wearables can collect a series of "Health" data, such as heart rate, body temperature and blood pressure, which can then be transmitted wirelessly to a remote site for storage and analysis. This is also applicable for diagnosing and treating patients remotely.

3.6.3. Transport:

The IoT can revolutionize transportation systems by improving people's lives.

For example, with connected cars, organizing your trips will become easier, you can avoid traffic jams, find a parking space and reduce traffic accidents.

Driverless cars will undoubtedly have the biggest impact. Many companies, such as Tesla, Google, Uber, Volvo, Volkswagen, Audi and General Motors, etc.,…are actively developing and promoting them. These smart cars can make our journey more enjoyable and possibly much safer.

The IoT can also improve the quality of public transport. By connecting all information boards and advertising boards at train stations and airports, it helps passengers to get regular updates and in the event of an accident, to quickly detect problems and reduce maintenance costs. By improving end-to-end visibility, warehouse management and fleet management.

3.6.4. Energy:

By integrating management techniques, it is possible to reduce the energy consumption of all electrical devices by installing sensors and actuators.

The IoT will modernize also the energy sector infrastructure and therefore improve efficiency and productivity.

3.6.5. The Environment:

With the various environmental sensors deployed, we can more effectively monitor air quality, water quality, soil conditions, radiation and hazardous chemicals. We can also better predict earthquakes and tsunamis and more quickly detect forest fires, snow avalanches and landslides. All of this will help us to better protect our environment. By tagging wild animals, especially endangered species, we can study and better understand animal behavior, and therefore provide better protections and safer habitats.

The IoT will also allow soil and crop quality to be monitored remotely and at any time of the day, making agriculture smart. This will inevitably have a positive impact on the environment.

3.7. The Interoperability

Interoperability is one of the major challenges of the IoT, and in the following, we will provide detailed information about it:

3.7.1. Definition

Interoperability can be defined as "*the ability to exchange services and data with one another. It is based on agreements between requesters and providers on, for example, message passing protocols, procedure names, error codes, and argument types* " [Heiler, 1995].

This definition poses certain challenges such as: Obtaining information, Data exchange and using information by understanding it and being able to process it.

3.7.2. The interoperability dimensions:

The figure 1.6 shows the different interoperability dimensions:

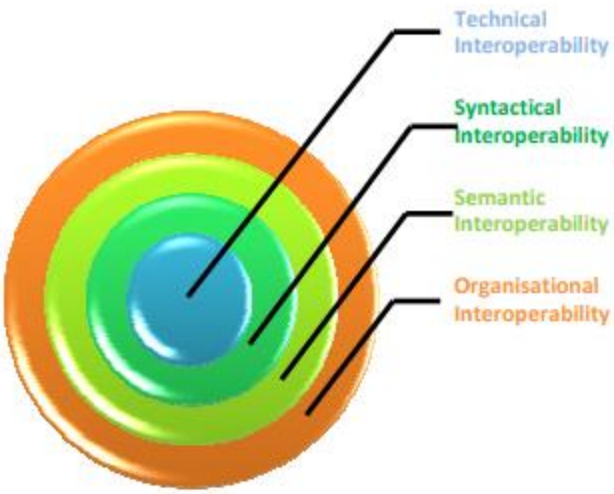

Figure 1.6: The interoperability dimensions
(Adapted from [Patel et al. 2016])

In the following we will explain in detail the different dimensions of the interoperability:

- ✓ **Technical Interoperability:** It is usually associated with software components and hardware, systems and platforms allowing the machines to communicate with each other. This type is often centered on the protocols and the infrastructure that is necessary to operate them.
- ✓ **Syntactical Interoperability:** It is generally associated with the data formats. The Messages that are transferred by protocols must adhere to some certain well-defined encoding although it is only in the form of bitmaps.

However, many bits carry data or content that can be represented using high-level transfer syntaxes such as HTML, XML, etc.

- ✓ **Semantic Interoperability:** It is usually associated with the meaning of the content. It concerns the interpretation of the latter by man instead of the machine.
  At this level, interoperability means that people commonly understand the meaning of the content (information) exchanged.

- ✓ **Organizational Interoperability :** As its name suggests, it expresses the ability of organizations to communicate as well as transfer meaningful data (information) in an efficient way, even if they use a variety of different information systems on very different infrastructures to across different geographies and cultures, This interoperability depends on successful technical, syntactic and semantic interoperability [Patel et al. 2016].

3.7.3. Difference Between Interoperability and Non-Interoperability

The following figures shows the difference between Interoperable IoT and Non-Interoperable IoT:

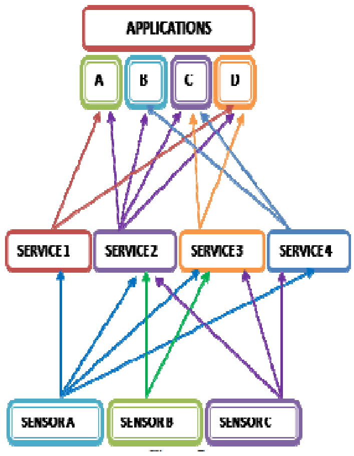

Figure 1.7: Interoperable IoT

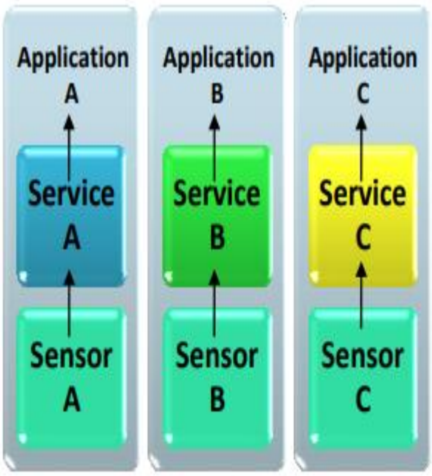

Figure 1.8: Non Interoperable IoT

(Adapted from [Patel et al. 2016])

3.7.4. The role of interoperability for IoT services/applications:

Technical interoperability is responsible for ensuring the correct transmission of bits without saying anything about what those bits mean or what they represent or whether they are voice, video or data.

It is the task of the syntax layer which is responsible for defining the syntax of particular services. The standards of these two layers make it possible to exchange data independently of the content, which is different in the semantic layer which is application-specific and dependent on service-specific content, and for organizational interoperability, it is application or service specific [Patel et al. 2016].

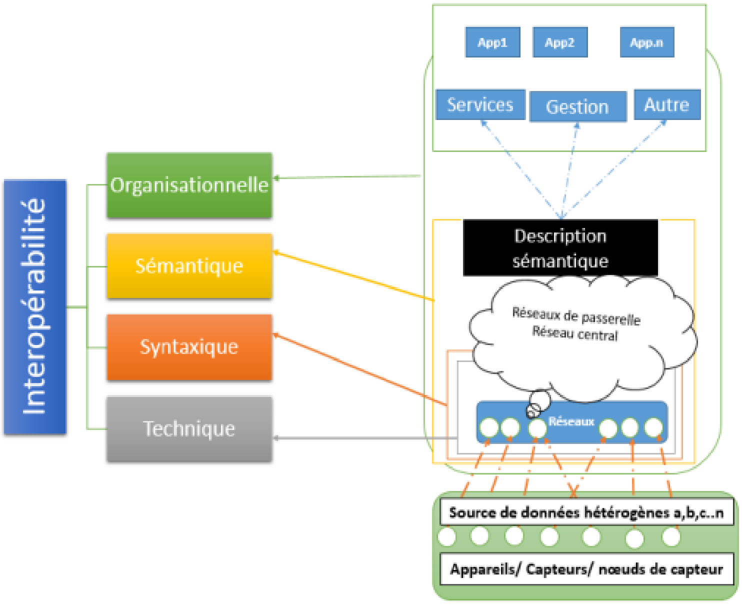

Figure 1.9: The role of interoperability for IoT services/applications

(Adapted from [Patel et al. 2016])

4. Semantic Web

4.1. Definition of the semantic web

The definition of the semantic web according to (Laublet et al, 2015) is as follow:

"*The Semantic Web, concretely, is first of all an infrastructure to allow the use of formalized knowledge in addition to the current informal content of the Web*.

Even if no consensus exists on how far this formalization should go. This infrastructure must first make it possible to locate, identify and transform resources in a robust and healthy way while reinforcing the spirit of openness of the Web with its diversity of users » [Laublet et al, 2015].

Tim Berners-Lee also defined the semantic web in another way: « The semantic web is a data network, a kind of global database » [Berners-Lee, 1999].

Through his creator Tim Berners-Lee the next evolution of the Web is about arriving at an intelligent Web, where information would no longer be stored but understood by computers in order to bring to the user what he really looking for. According to Tim Berners-Lee's definition, the Semantic Web will make it possible (unlike the current Web which is seen as a syntactic Web) to make semantic content of Web resources interpretable not only by humans but also by machines [5].

4.2. The architecture of the semantic web

The semantic web architecture is shown in the figure below:

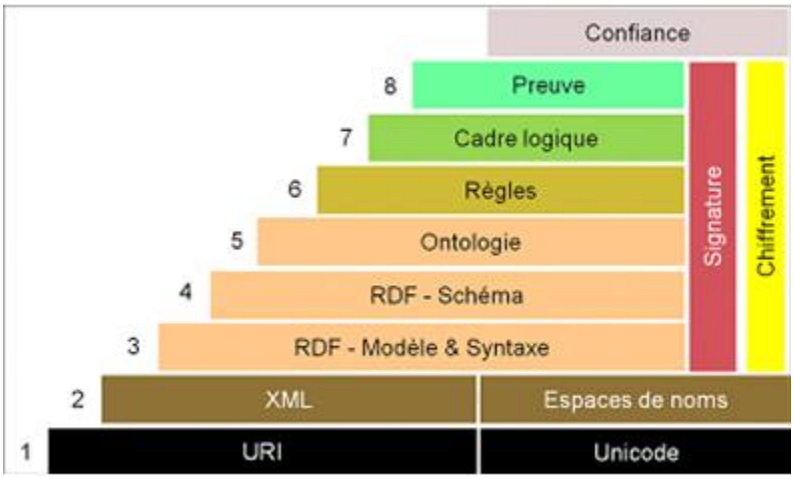

Figure 1.10: The architecture of the semantic web [6].

4.3. Semantic Web Languages

4.3.1. Ontologies

Ontologies are one of the basic concepts of the Semantic Web, its definition according to (Charlet et al, 2005) is as follow: "*A set of objects recognized as existing in the field. To build an ontology is also to decide on the way of being and existing of objects*" [Charlet et al, 2005].

In this definition, objects are not taken in a sense computing but as real-world objects that the system models.

To continue towards a definition of ontology, it seems to us essential to remember that work on ontologies is developed in an IT context – whether that of Knowledge engineering, artificial intelligence or management and information systems or more specifically here the context of the Semantic Web, where the end goal is to specify a computing artifact. In this context, the ontology then becomes a model of existing objects which refers to it through concepts, the concepts of the domain [Charlet et al, 2005].

Another simple definition given by (Gruber, 1993) and (Studer, 1997) is as follow: "*An ontology is an explicit and formal specification of a* conceptualization "[Gruber, 1993].

4.3.2. Resource Description Framework: RDF

According to (Charlet et al, 2003): « RDF is a formal language that makes it possible to affirm relations between "resources". It will be used to annotate documents written in unstructured languages, or as an interface for documents written in languages with equivalent semantics (Data bases for example) » [Charlet et al, 2003].

The RDF model is represented by forming a graph connecting two nodes (Subject and Object) by a well-directed arc (Property) as it shown in the figure below:

Figure 1.11: RDF Graph(Adapted from [Prasad et al. 2021])

An RDF document is a set of triplets of the form <subject, predicate, object. The elements of these triplets can be URIs (Universal Resource Identifiers), literals or variables.

This set of triples can be represented in a natural way by a graph (more precisely a labeled directed multi-graph), where the elements appearing as subject or object are the vertices, and each triple is represented by an arc whose origin is its subject and the destination its object. This document will be machine-coded by an RDF/XML, but is often represented in graphical form [Charlet et al, 2003].

The semantics of RDF is obtained while linking with the RDF Schema language (RDFs) and the language of the Ontological Web (OWL) which represent two other technologies or languages of the Semantic Web.

4.3.3. RDF Schema : RDFS

RDFS (RDF Schema) aims to extend the language by describing more precisely the resources used to label the graphs. It does this by providing a mechanism to specify the classes of which resources will be instances, such as properties. RDFS extends RDF to include a schematic vocabulary such as: Class, Property, SubClassOf, SubPropertyOf, Domain, Range...etc [Baget et al, 2013].

4.3.4. Ontology Web Language : OWL

RDF, a language dedicated to expressing assertions about relationships between objects, came up against the need to define the properties of the classes of which these objects are instances. However, the extension to RDFS only provides primitive mechanisms for specify these classes. The OWL language, on the other hand, is dedicated to the definition of classes and types of properties, and therefore to the definition of ontologies. Inspired by description logics (and successor to DAML+OIL)), it provides a large number of constructors allowing the properties of the defined classes to be expressed in a very fine manner. The ransom of this expressivity is the undecidability of the language obtained by considering the set of these constructors. This is why OWL has been split into three distinct languages:

1. **OWL-Full**: a union of OWL & RDF syntax
2. **OWL-DL**: Restricted to FOL (First Order Logic) fragment
3. **OWL-Lite**: A subset of OWL DL that is easy to run [Baget et al, 2013].

4.3.5. Simple Protocol and RDF Query Language : SPARQL

Pradel (Pradel et al, 2012) has defined The SPARQL query language as a language that allows to express queries in an "SQL-like" syntax. It nevertheless requires expressing queries in the form of graphs (sets of RDF triples) which is unthinkable for an end user [Pradel et al, 2012].

4.3.6. Semantic Web Rule Language: SWRL

SWRL (Semantic Web Rule Language) is a rules language for the semantic web, combining OWL-DL and RuleML (Rule Markup Language (Unary/Binary Datalog)) which has made it possible to further improve the logic of descriptions while using rules and thus to be able to overcome the limits of ontological languages. It is a homogeneous approach whose SWRL rules are integrated [7].

4.4. Semantic Web Application Areas

The semantic web is applied in a lot of fields

Some of them are:

- ✓ Software agents
- ✓ Semantic office
- ✓ Health care
- ✓ Agriculture
- ✓ Geospatial semantic web

5. Semantic Web of Things SWoT / Semantic Internet of Things SIoT

5.1. SWoT definition

The definition given by (Jara et al, 2014) is as follow: **"**The SWoT is, on the one hand, the fusion of the trends of the IoT for moving towards the web technologies with protocols such as CoAP, REST architecture and the Web of Things concept, and, on the other hand, the evolution of the web with the semantic web technologies"**.** [Jara et al, 2014].

It can also be defined simply as a combination of the Semantic Web (SW) and the Internet of Things (IoT).

Figure 1.12 shows the phases that IoT should follow to become a semantic IoT powered by web technologies:

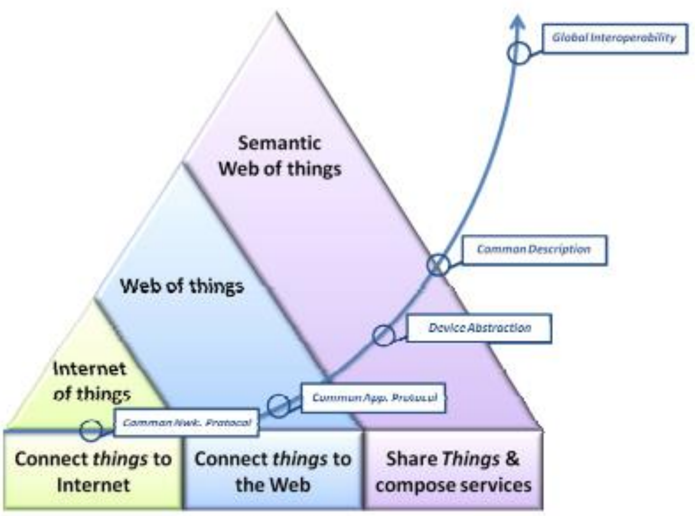

Figure 1.12: From the IoT to the SWoT (Adopted from [Jara et al, 2014])

5.2. The characteristics of SW combined with IoT

Researchers have extended the features that SW has with IoT, including:

- Widespread use of URIs and the HTTP protocol
- Connecting domain models through interoperable references
- Use of common standard languages
- Domain expressivity by extrapolation of logical sequences [Chatzimichail et al, 2021].

5.3. SWoT challenges

Moving from the IoT/WoT to the SWoT is challenging. Some of the challenges are defining a common description that allows data to be universally understandable, creating extensible annotations, which means from minimal semantic descriptions towards more elaborate ones, and agreeing on a catalogue of semantic descriptions (ontologies). Some of the other challenges are as follow:

- ✓ The evolutionary growth of IoT systems with multiple devices.
- ✓ The ability to interconnect devices from various vendors
- ✓ The ability of developing software applications for IoT environments by open-source software developers.
- ✓ The development of applications for generic domains using data from different sensors [Chatzimichail et al, 2021].

5.4. SWoT Architecture :

The following figure shows the architecture of the SWoT discipline which combines the Semantic Web and the Internet of Things:

Figure 1.13: semantic web stack for IoT
(Adopted from [Szilagyi et al, 2016])

The figure above shows the main SW technologies at different levels of an IoT system. Where the identification of the integration of the semantic web into the IoT can pass through three levels which are:

- ✓ **The modeling level:** It provides a common understanding of Things' characteristics and capabilities through the use of common accepted vocabularies and ontologies in order to facilitate the integration of data generated by different systems (e.g., sensor ontologies).
- ✓ **The data processing level:** Through the use of description logics and OWL semantics for the reasoning and inference over the data.
- ✓ **The IoT services and application level:** The specialized description and ontologies at this level enables service publication, discovery, composition and adaptation [Szilagyi et al, 2016].

- ❖ **Models and meta-models:** The models and meta models' layer is concerned with data preparation. Where the data interpretation and understanding is the first prerequisite in this process. This layer manages the semantic integration and aggregation of data from a variety of sources. Semantically annotated data can be transformed and modeled according to specific needs.

- ❖ **Data processing:** IoT is an original distributed system which can make processing of its data at different levels. When there are multiple sources from which data originates which is subsequently collected, processed and correlated. Two different approaches are highlighted for the treatment of the latter which are:

1. The use of semantic reasoners.
2. The use of specific algorithms to Big Data (e.g. machine learning).

- Reasoning and Inferences. Rules and semantic alignments (e.g. *owl: equivalentClass, owl: subClassOf*, *owl: sameAs*) can be used to transform and adapt the data to the declared ontologies.
- Big Data and machine learning algorithms. Semantic Technologies are an excellent choice for IoT systems for two reasons. The first one, because it allows sharing the data description through schemas and ontologies and the second because it allows knowledge encoding in ontologies via description logic constructs.

❖ **IoT services and applications:** the description of the provided services can be enhanced by the ontologies and semantic annotations. OWL-S provides semantic markup for web services.

6. Related Works:

Authors in (Pinto et al, 2020) have proposed an IoT-based Health Care System for elderly People. Its name is "We-Care". It can be considered as an IoT-ready solution for the elderly living assistance which is able to monitor and register patients' vital information as well as to provide mechanisms to trigger alarms in emergency situations. Its effective low power/low-cost and wireless characteristics turns this solution suitable to be used anywhere and by anyone. The figure below shows the architecture of the "We-Care" system:

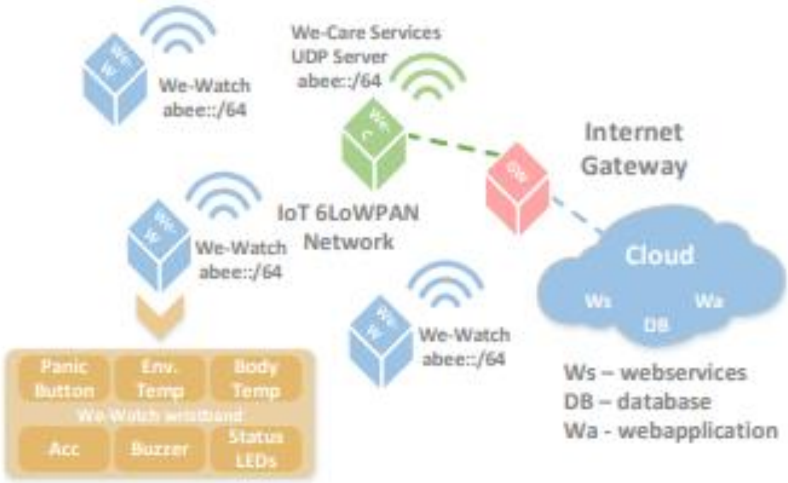

Figure 1.13: We-Care system architecture.

The system architecture is composed by three main components which are We-Watch wristband, the We-Care services board and the cloud services. The We-Watch consists of a discrete small sized wristband that is responsible to monitor and collect data from the available sensors and send it securely to the We-Care board in order to run the web services and interface the cloud when an Internet gateway is available. In a case of an emergency, it provides an alarm to the caretaker, enabling a fast response to any possible problem. All these features enables the system to remotely monitor any elderly person without their physical presence

[Pinto et al, 2020].

Authors in (Ferreira et al, 2013) proposed a mobile health application dedicated to the elderly allowing communication between these people and their caregiver. This application is made for a specific model called Protégé which has the functionality of sending a request for help (SOS) from the elderly person to his caregiver following this algorithm:

- ✓ GPS location of the person who needs help.
- ✓ Sending an SMS the GPS position to the helper as well as calling him [Ferreira et al, 2013].

Authors in (Mainetti et al, 2017) proposed an Ambient Assisted Living (AAL) which is a system designed to create better living conditions for older people, Using this system elderly can live independently longer in their own house with an improved quality of life. This system includes several features. On the one hand, it is able to continuously monitor the health status of the elderly through data coming from heterogeneous sources (i.e., environmental sensors and medical devices). On the other hand, it is able to guarantee outdoor and indoor localization aimed to know the real-time position of the elderly both inside and outside their home. A remote reasoning system processes all collected data with the aim of generating appropriate events and alerts [Mainetti et al, 2017]. The figure 1.14 shows the architecture of this proposed system:

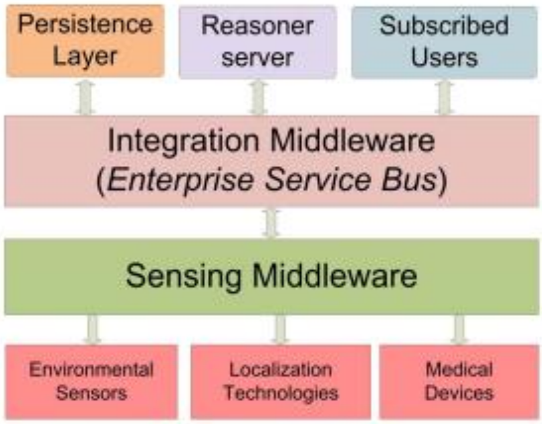

Figure 1.14: AAL Architecture (Adopted from [Mainetti et al, 2017])

Hulsure et al (2020) proposed a system that aims to provide immediate help for an elderly or motor-disabled or young person finding it difficult to move while using an accelerometric sensor to detect the fall, also providing a button to aid conveniently located in the wheelchair for instantaneous help request to the user or Buzzer provided to be able to notify the nearest people. An Android application is also used for all types of notifications in which any location of the wheelchair is displayed using GPS. This system has two parts: One is hardware and the other software. The Android application is used as an intermediary that displays the actions entered by the user, the Arduino is used as a controller for any movement based on the key entered by the user (move left, right, forward, backward or stop) [Hulsure et al, 2020].

Authors in (Yacchirema et al, 2018) proposed an innovative IoT-based system for detecting falls of elderly people in indoor environments, which takes advantages of low-power wireless sensor networks, smart devices, big data and cloud computing. For this purpose, a 3D-axis accelerometer embedded into a 6LowPAN device wearable is used, which is responsible for collecting data from movements of elderly people in real-time. To provide high efficiency in fall detection, the sensor readings are processed and analyzed using a decision trees based Big Data model running on a Smart IoT Gateway. If a fall is detected, an alert is activated and the system reacts automatically by sending notifications to the groups responsible for the care of the elderly people. Finally, the system provides services built on cloud

[Yacchirema et al, 2018].

7. Conclusion

At the end of this chapter, we have shown the technical aid which can subsequently facilitate the daily life of the elderly. What will be discussed in the following chapter is the technical approach that will be applied in this work with more details.

Chapter 2: Design

1. Introduction

With the technological evolution that the world is experiencing today, many people are benefiting from the help that technology can offer in quite a few daily tasks and that is the case for people who are in need whatever their type (elderly or not) and the disciplines technologies that allow this type of people who are in need to live a better and more independent life and of course in better conditions.

In this chapter, we will detail the approach that we will use as a technical solution in order to be able to offer the necessary assistance to people in need and which is cited already in the previous chapter under the name of "Semantic Web of Objects" while presenting the architecture of the system based on this approach as well as all the elements that build it.

2. Objective of the proposed approach

This approach, as already defined above, has two main objectives which are as follows:

- ✓ Ensure interoperability between different heterogeneous IoT systems (information collected from sensors, etc.).
- ✓ Inference which results in new facts and therefore new knowledge and a well-enriched knowledge base.
- ✓ Based on the new knowledge’s and a semantic reasoning a prediction model will be built and the system will predict the health problems that could happen to the elderly people and will alert the concerned sectors and ask for help.

3. The functional architecture of the system

The components making up the system are as shown in Figure 2.1 below:

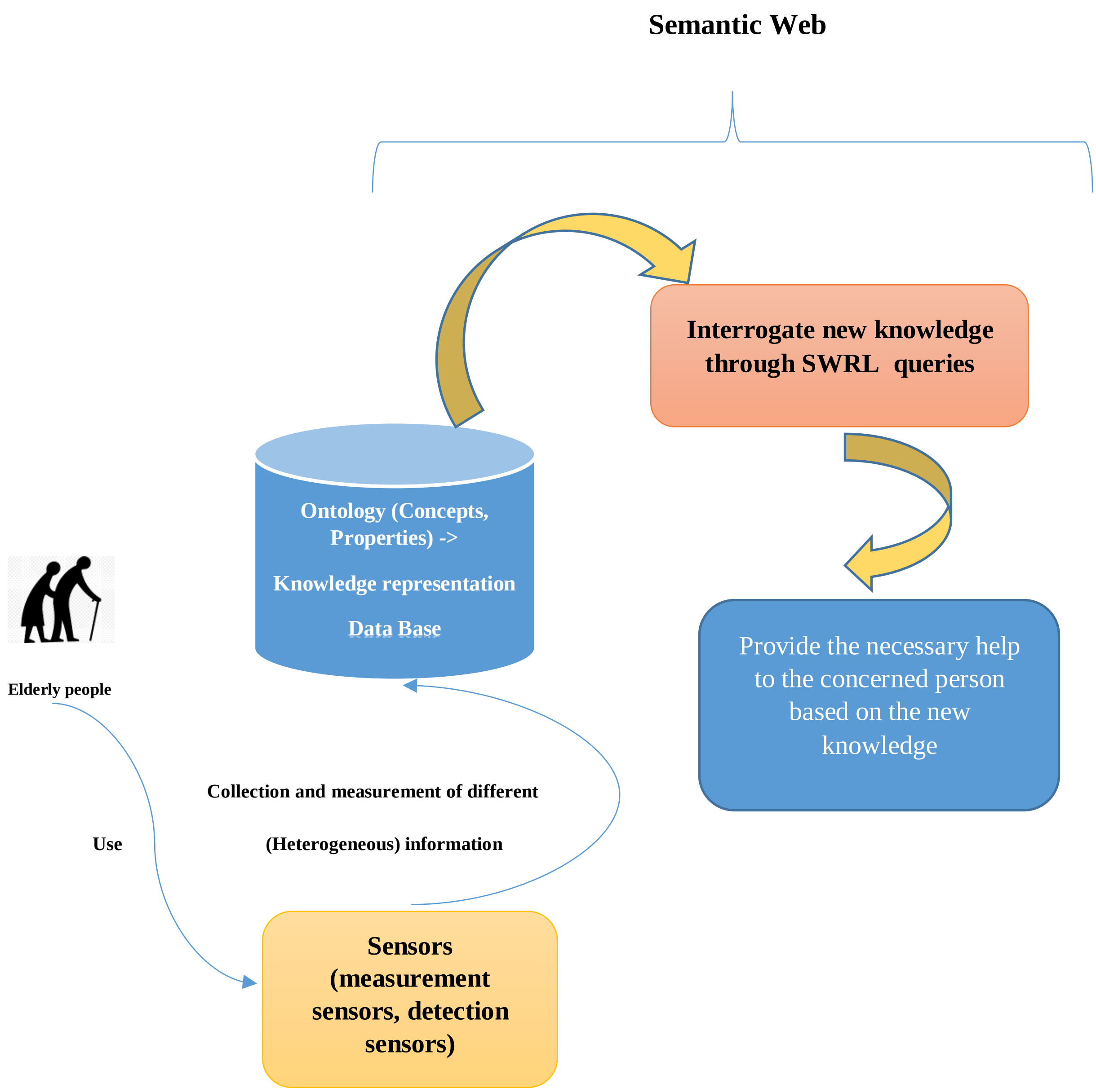

Figure 2.1: How the system work

4. Explanation of the process

By using sensors of different types (measurement sensors, detection sensors) that a person can wear, the system collects information such as temperature, respiration and heart rate..., And by using the ontology, interoperability will be guaranteed between the different IoT systems by a formal representation of each concept followed by its properties and therefore a representation of knowledge.

Based on a SWRL reasoning and inference engine, new knowledge’s will be added which increasingly enriches the knowledge base, Based on new knowledge the prediction model will be built which will be used to alert the sectors concerned and ask for help.

5. Knowledge representation

In the context of the present work, the ontology created makes it possible to describe the knowledge in the field of public health which aims to follow and help people who are in need (the elderly people) By using concepts, properties in order to formally describe the knowledge in the targeted domain. The ontology is created by following the iterative method proposed by Noy and MCGuinness ([Noy et al., 2001]), because the iterative method reduces the complexity of ontology development, since it divides it into small parts thus in our process the knowledge acquisition is made incrementally, which facilitates the understanding of the subject and for the respect of construction principles we have applied Gruber ([Gruber, 1993]).

5.1. Ontology Concepts / Classes (Ontology 101):

Within the proposed ontology, the terms are grouped together in the form of the concepts presented in the following:

1. **Person**
2. **Vital_Signs**
   -Body_Temperature
   -Respiration_Frequenc
   -Pulse_Rate / Heart_Rate
   -Blood_Pressure
   -Blood_Sugar

3. Devices

-GPS

-Sensors

-Measurement_Sensors

-Medical_Sensors

-Body_Temperature_Sensor

-Respiration_Frequency_Sensor

-Pulse_Rate_Sensor

-Blood_Pressure_Sensor

-Blood_Sugar_Pressure

-Weather_Sensors

- Accelerometer

-Detection_Sensors

-RFID

-Actuator

-Alert

-Opening_Window

-Opening_Door

-Emergency_button

-Medical_Alarm

-Wearable_Devices

-Smart_Watch

-Eye_Glasses

4. Symptoms

-Abdominal_Sweling

-Back_Pain

-Chest_pain

-Chills

-Cough

-Dizziness

-Double_vision

-Eye_Color_Red

-Fainting

-Fatigue

-Fever

-Head_ache

-Nausea

-Pain_above_behind_eyes

-Paleness

-Shortness_of_Breath

-Swelling_of_feet

-Vomiting

5. Diseases

-Prediabetes

-Diabetes

-Digestive_System_diseases

  -Diarrhea

-Cholangiocarcinoma_Disease

-Acute_Pancreatitis

-Heart_Diseases

-Heart_attacks

-Cardiac_Failure

-Cardiac_Tamponade

-Coronary_Heart_Disease

-Endocarditis

-Nervous_System_Diseases

-Memory_Disorders

-Stroke

-Brain_aneurysm

-Brain_Tumor

-Vascular_Diseases

-Hypertension

-Aneurysm

6. Obstacles

-Fire

-Stairs

-Wall

-Pit

-Weather_conditions

-rain

-snow

-wind

-fog

7. **Activities**

-Medical_visit

-Ride

-Shopping

-Rest

8. **Help_providers**

-Ambulance

-FireFighters

-General_Doctor

-Hospital

-Specialist_Doctor

9. Medicament

10. Message

-Text_Message

-Vocal_Message

5.1.1. Concepts / Classes Explanation (Construction of glossary of terms):

- ✓ **Person:** This class represents the involved people using this system which are most often elderly people.
- ✓ **Vital_Signs:** As its name indicates, it represents the vital signs of each of the people targeted, including blood pressure, blood sugar, body temperature, heart rate, respiration rate and each one includes three levels which are: low, normal and high.

- ✓ **Devices:** This class represents any device used to measure the vital signs of a target person and any device that can provide help to people who need it as well as follow them in their daily lives, and includes the following sub classes :

- **Sensors:** (contains two types those which are intended for detection and others that are intended for measurement).
- **Actuator:** an actuator is a device that produces a motion by converting energy and signals going into the system
- **Wearable Devices:** includes some devices that could be helpful for the elderly and that facilitate their daily lives such as: smart watches, smart eye glasses...etc.
- GPS.

✓ **Symptoms:** This class includes the most common symptoms of some diseases and health problems that elderly people may experience, some of these symptoms are: Shortness of breath, Head_ache, vomiting, coughing...etc.

✓ **Diseases:** This class represents the most common diseases for elderly, which can be predicted before and seek help and intervention from the doctors and the other relevant authorities in a timely manner, It includes four subclasses which are: Heart diseases, Nervous system diseases, Digestive system diseases, Vascular diseases, Diabetes, Prediabetes.

✓ **Help_providers:** This class includes the authorities which will be able to receive requests for help in the event of any danger such as: the ambulance, the firefighters..., and also the doctors who will be able to monitor the health situation of the elderly.

✓ **Obstacles:** This class represents the obstacles that can be faced by the elderly and that can affect their daily activities such as: fires, stairs, and it includes also the weather conditions such as: rain, snow, wind, fog...etc.

✓ **Activities:** It represents the important activities of the elderly such as: the medical visits, the shopping, the ride...etc.

✓ **Message:** This class includes the message that will be sent to an elderly person or to the authorities concerned with providing assistance, it could be a vocal or text message.

✓ **Medicament:** This class concerns whether the elderly person has medication in order to remind him when it is time to take it.

Concepts	**Description**
Person	Concept that represents all the targeted people included in the system.
Vital Signs	Concept that represents all measured vital signs of the targeted person which are: Blood pressure, Blood sugar, Respiratory rate, Pulse rate, Body temperature.
Devices	Concept that includes all the tools used for the measurement of the vital signs or the detection of the obstacles such as: RFID, medical sensors.
Symptoms	Concept that includes all possible symptoms that a patient may experience.
Diseases	Concept that includes all possible diseases that a patient may have.
Help providers	Concept that includes all authorities responsible for providing assistance such as: hospitals, ambulance.

Obstacles	Concept that includes all possible obstacle that a person may face like weather conditions such as: snow, rain.
Activities	Concept that includes the daily activities practiced by the person such as: promenade, medical visit.

Table 2.1: Concepts/ Classes description

5.2. Object properties

Objects are connected to each other by relationships that will be presented in the following:

- ✓ **Has_Sensor (person, Sensors):** defines a person who wear sensor devices (measurement or detection sensors) in order to measure his vital signs or detect some obstacles.
- ✓ **HasVitalSigns (person, Vital_Signs):** defines that a person has one of such vital signs, it contains subproperties such as: HasBodyTemperature, HasRespirationFrequency, HasBloodPressure, HasBloodSugar and HasPulseRate with their different levels (low, normal, high).
- ✓ **Has_Measurement (Medical_Sensors, Vital_Signs):** defines the fact that a sensor measure and record one of the vital signs of the targeted person.
- ✓ **Has_Obstacle (Detection_Sensors, Obstacle):** defines the fact that a detection sensor detect an obstacle and alerts the targeted person.
- ✓ **Apply_Action (person, Actuator):** Expresses the fact that an actuator provide automatically some assistance to the persons in need such as: opening door or windows, medical alarm...etc.

- ✓ **Has_Symptoms (person, Symptoms):** It expresses the fact that a person has some symptoms that indicate the possibility of some diseases that require medical intervention.
- ✓ **Has_Disease (person, Diseases):** as its name suggest, it expresses the fact that a person has a certain disease.
- ✓ **Send_Message (Person, Help_providers):** As its name indicates, it is to send a message to those concerned with providing assistance such as: ambulance, hospital...etc.
- ✓ **Locate_Position (GPS, person):** As its name suggests, thanks to the GPS it can follow the movement as well as know the position of the targeted person.
- ✓ **IsSymptomOf (Symptoms, Diseases):** As its name suggests, it expresses that a certain disease has the indicated symptoms.
- ✓ **Help (Holding_Devices, person):** It provides them with help through the wearable devices such as smart watches...etc.
- ✓ **Doing_Activity (person, Activities):** It expresses the fact that a person do certain activities such as: medical visits.
- ✓ **Has_Medicament (person, Medicaments):** As its name indicates, it expresses the possibility of following a medicine by the person concerned in order to remind him or help him to take it regularly.

Object properties	**Domains**	**Ranges**
Has_Sensor	person	Sensors
Has_Measurement	Medical_Sensors	Vital signs
Has_VitalSigns	person	Vital signs
Has_Obstacle	Detection_Sensors	Obstacles
Apply_Action	person	Actuator
Has_Symptoms	person	Symptoms
Has_Disease	person	Diseases
Send_Message	person	Help_Providers
Locate_Position	GPS	person
IsSymptomOf	Symptoms	Diseases
Help	Holding_Devices	person
Doing_Activity	person	Activities

Table 2.2: Object properties description

5.3. Data properties:

Data properties are presented in the following:

- ✓ **Has_name:** indicates the name of the person.
- ✓ **Has_Age:** indicates the age of the person.
- ✓ **Has_Sex:** indicates the sex of the person.
- ✓ **Has_Adress:** indicates the address of the person.
- ✓ **Has_Value:** indicates the value of the vital sign measured by the measurement sensors, such as: Body Temperature value, Has_RespirationFrequency value…etc.
- ✓ **Has_Time:** indicates the measurement time of the vital sign.

We can summarize everything that is shown above in the following diagram:

Data properties	**Domains**	**Ranges**
Has_name	Person	String
Has_sex	Person	String
Has_Adress	Person	String
Has_Age	Person	String
Has_Value	Vital signs	Integer
Has_Time	Vital signs	Integer

Table 2.3: Data properties description

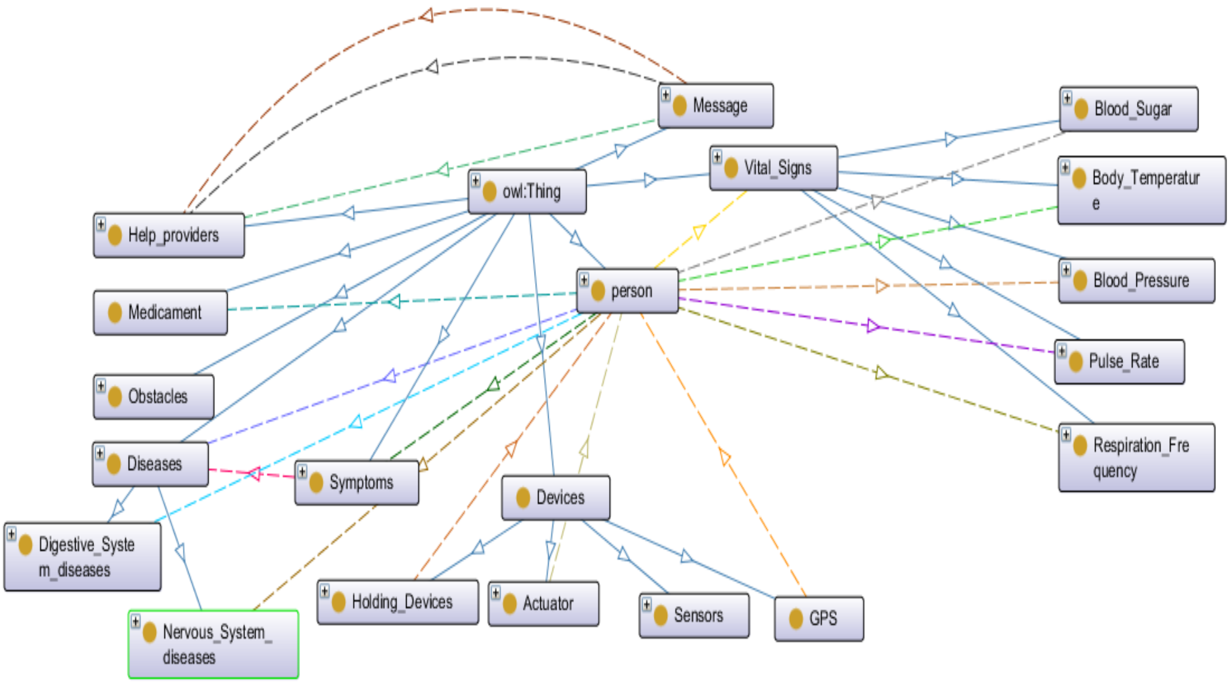

Figure 2.2: The ontology Diagram

6. Semantic-based prediction model / Inference rules with SWRL language

Here some SWRL rules was applied, in order to get new knowledge's that will be used in the prediction of the health problems:

- ✓ **Rule 1:** The first rule refers to the fact that if a person who wears some medical sensors have a low respiratory rate, high blood pressure and a high pulse rate, these factors can be indicative of the possibility of a heart attack, So in this case a message will be sent to the ambulance to intervene in the right time to avoid any danger.

person(?x) ^ Blood_Pressure_Sensor(?y) ^ Respiration_Frequency_Sensor(?z) ^ Pulse_rate_sensor(?w) ^ Has_Sensor(?x, ?y) ^ Has_Sensor(?x, ?z) ^ Has_Sensor(?x, ?w) ^ Blood_Pressure(?bp) ^ Respiration_Frequency(?rf) ^ Pulse_Rate(?pr) ^ Has_Measurement(?y, ?bp) ^ Has_Measurement(?z, ?rf) ^ Has_Measurement(?w, ?pr) ^ Has_Value(?bp, ?v1) ^ swrlb:greaterThan(?v1, 130) ^ Has_Value(?rf, ?v2) ^ swrlb:lessThan(?v2, 12) ^ Has_Value(?pr, ?v3) ^ swrlb:greaterThan(?v3, 100) ^ Shortness_of_Breath(?shb) ^ Heart_attacks(?ha) ^ Ambulance(?am) -> Has_Symptoms(?x, ?shb) ^ Has_Disease(?x, ?ha) ^ Send_Message(?x, ?am)

- ✓ **Rule 2:** If a person have a very high body temperature, this may be an indication of a fever, so with unstable climatic conditions such as: snow, rain that could affect on his health, an alert will be sent to the person to prevent him from going outside.

person(?x) ^ Body_Temperature_Sensor(?y) ^ Has_Sensor(?x, ?y) ^ Body_Temperature(?z) ^ Has_Measurement(?y, ?z) ^ Has_Value(?z, ?v) ^ swrlb:greaterThan(?v, 38) ^ Fever(?f) ^ RFID(?rfid) ^ Has_Sensor(?x, ?rfid) ^ Snow(?sn) ^ Has_Obstacle(?rfid, ?sn) ^ Alert(?a) -> Has_Symptoms(?x, ?f) ^ Apply_Action(?x, ?a)

- ✓ **Rule 3:** If a person have a very high blood sugar level, more than 200 mg/dL, this can be an indicative of diabetes, so in this case a message will be sent to the specialist doctor for some medical advice.

person(?x) ^ Blood_Sugar_Sensor(?y) ^ Has_Sensor(?x, ?y) ^ Blood_Sugar(?bs) ^ Has_Measurement(?y, ?bs) ^ Has_Value(?bs, ?val) ^ swrlb:greaterThan(?val, 200) ^ Diabetes(?d) ^ Specialist_Doctor(?sd) -> Has_Disease(?x, ?d) ^ Send_Message (? x, ?sd)

- ✓ **Rule 4**: This rule expresses the fact that if a person have these symptoms: abdominal swelling, Chills, Cough, Fatigue, Fever, Paleness and Shortness of breath, all these symptoms can indicates the existance of the disease endocarditis, So in this case a message will be sent to the hospital with the location of the patient.

person(?x) ^ Abdominal_Sweling(?y) ^ Chills(?z) ^ Cough(?w) ^ Fatigue(?f) ^ Paleness(?p) ^ Body_Temperature_Sensor(?s1) ^ Respiration_Frequency_Sensor(?s2) ^ Has_Sensor(?x, ?s1) ^ Has_Sensor(?x, ?s2) ^ Body_Temperature(?bt) ^ Respiration_Frequency(?rf) ^ Has_Measurement(?s1, ?bt) ^ Has_Measurement(?s2, ?fr) ^ Has_Value(?bt, ?v1) ^ Has_Value(?rf, ?v2) ^ swrlb:lessThan(?v2, 12) ^ swrlb:greaterThan(?v1, 38) ^ Has_Symptoms(?x, ?y) ^ Has_Symptoms(?x, ?z) ^ Has_Symptoms(?x, ?f) ^ Has_Symptoms(?x, ?w) ^ Has_Symptoms(?x, ?p) ^ Endocarditis(?En) ^ Hospital(?h) -> Has_Disease(?x, ?En) ^ Send_Message(?x, ?h)

- ✓ **Rule 5:**

  Like the previous rule, if a person have these symptoms: Double vision, Dizziness, Giddiness, Headache and numbness of the face, arm and legs, All of these symptoms indicates the possibility of a stroke, So a message will be sent to the ambulance with the location of the patient to request a medical intervention.

person(?x) ^ Double_vision(?y) ^ Dizziness(?w) ^ Giddiness(?z) ^ Head_ache(?h) ^

Numbness_of_the_face/arm/leg(?f) ^ Has_Symptoms(?x, ?y) ^

Has_Symptoms(?x, ?w) ^ Has_Symptoms(?x, ?z) ^ Has_Symptoms(?x, ?h) ^

Has_Symptoms(?x, ?f) ^ Ambulance(?a) ^ GPS(?gps) ^ Locate_Position(?gps, ?x) ^

Text_Message(?M) ^ Stroke(?s) -> Has_Disease(?x, ?s) ^ Send_Message(?M, ?a)

- ✓ **Rule 6:** If a person have a low respiration frequency which means shortness of breath and while he is doing one of his daily activities he met a fire, so in this case an alert will be sent to the person to avoid going through this obstacle, because it can affect more on his respiratory rate.

person(?x) ^ Respiration_Frequency_Sensor(?y) ^ Has_Sensor(?x, ?y) ^
Respiration_Frequency(?z) ^ Has_Measurement(?y, ?z) ^ Has_Value(?z, ?val) ^
swrlb :lessThan(?val,12) ^ RFID(?rf) ^ Has_Sensor(?x, ?rf) ^ Fire(?fr) ^
Has_Obstacle(?rf, ?fr) ^ Shortness_of_Breath(?sh) ^ Alert(?al) ^ ride(?ri) ^
Doing_Activity(?x, ?ri) -> Has_Symptoms(?x, ?sh) ^ Apply_Action(?x, ?al)

7. Application scenario

Taking a real example of a person in need, Based on the proposed system which combines between the Internet of Things (IoT) and the Semantic Web, the steps to follow are:

- ✓ Introduction of the targeted person's information (name, age, sex, address) (the targeted person could be an elderly person), as well as the activity practiced by him such as: shopping, medical visit.
- ✓ Introduction of the measured vital signs of the targeted person such as: his body temperature, his pulse rate, his blood pressure, as well as some captured information such as: the existence of some obstacles on his way like stairs, wall, and fires.

- ✓ as a third step, based on the ontological model, rules based on the inference engine will be applied on the knowledge already defined in the ontology in order to obtain new knowledge, for example if a person have a low respiration frequency, The system can predict that this person is experiencing shortness of breath, In addition to that if he has high blood pressure and high pulse rate, So in this case it can predict the possibility of a heart attack, At the end all these new knowledge will be added to the knowledge base which will be used in the next step of the process.
- ✓ As a last step and using a rich knowledge base, the system will provide the appropriate assistance to each person as recommendations, alerts and help requests from the relevant authorities.

8. Conclusion

In this chapter, we presented the objective of the proposed approach as well as the architecture of the system while shedding light on the Semantic Web technologies that guarantee interoperability between the different sensors. Then, we also presented the ontological model (of its concepts, its properties linking the objects and those which are linked to the data) followed by the SWRL rules.

Chapter 3: Implementation

1. Introduction

In this chapter, we will present the application of the concepts mentioned in the previous chapters. First, we will present the development tools used to achieve the proposed system and then screenshots will be presented containing the ontological model on which the proposed system relies. At the end the results of some SWRL rules will be presented.

2. Development tools

Protégé 5.5.0

Protégé-2000 is an open-source tool that helps users build huge electronic knowledge bases. It has an intuitive user interface allows-both developers the creation as well as the modification of domain ontologies that represent the concepts and the most important relationships that connect them. From the ontology, the system builds a graphical knowledge acquisition system allowing application specialists to capture the content knowledge required for applications. Specific. Protégé-2000 is written in Java, and therefore runs on a wide variety of operating systems.

Protégé-2000 is available under the open-source license and can be downloaded from: https://protege.stanford.edu/ [Noy et al., 2003].

Programming Language Python

Python is a general-purpose, high-level interpreted programming language. Its design philosophy emphasizes code readability through the use of heavy indentation. Its language constructs as well as its object-oriented approach aim to help programmers write clear and logical code for small and large projects.

3. The ontological model

Figure 3.2 shows the creation of the necessary concepts on the Protégé-2000 platform which include the possible knowledge:

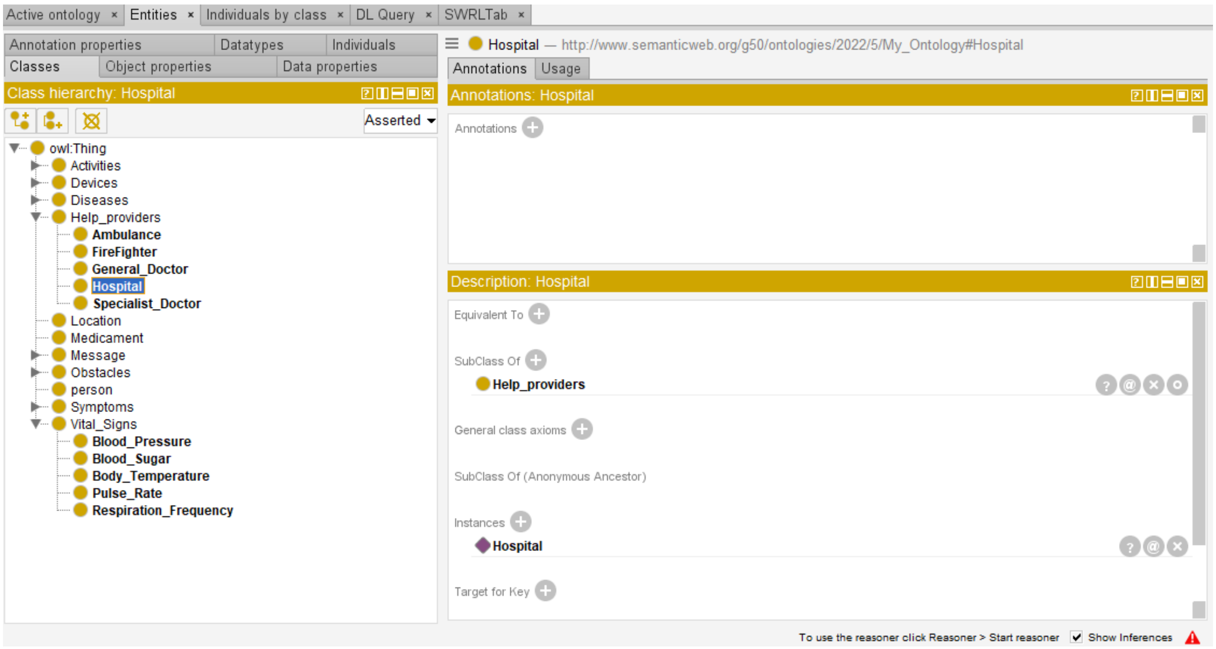

Figure 3.2: Concept creation on the protègè-2000 platform

And here is the class hierarchy after the creation:

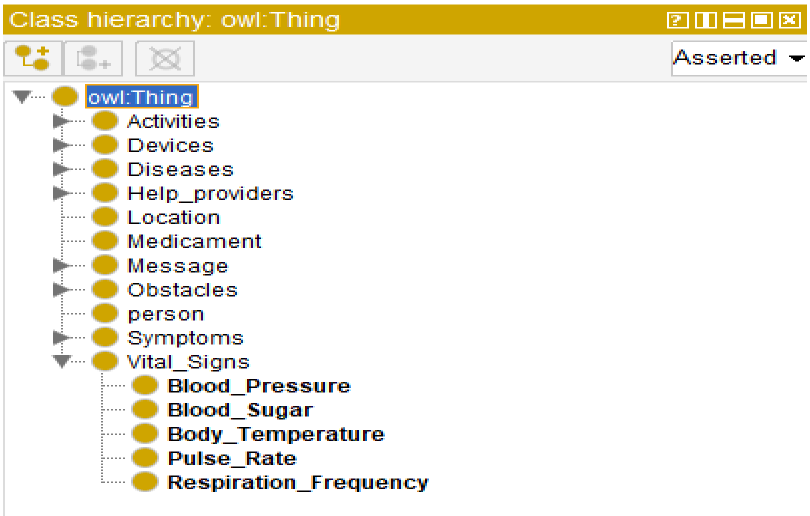

Figure 3.3: Class Hierarchy of the system

The relationships between the concepts which are the object properties presented above are shown in Figure 3.4:

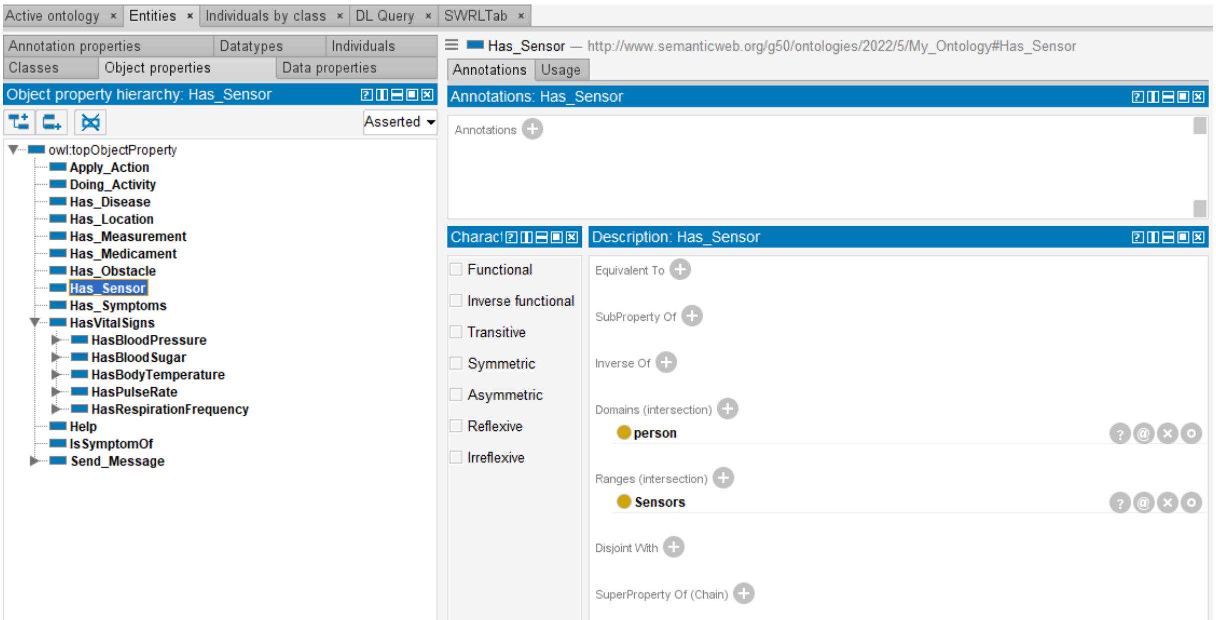

Figure 3.4: Object properties creation on the protègè-2000 platform

Object property hierarchy presented in the figure below:

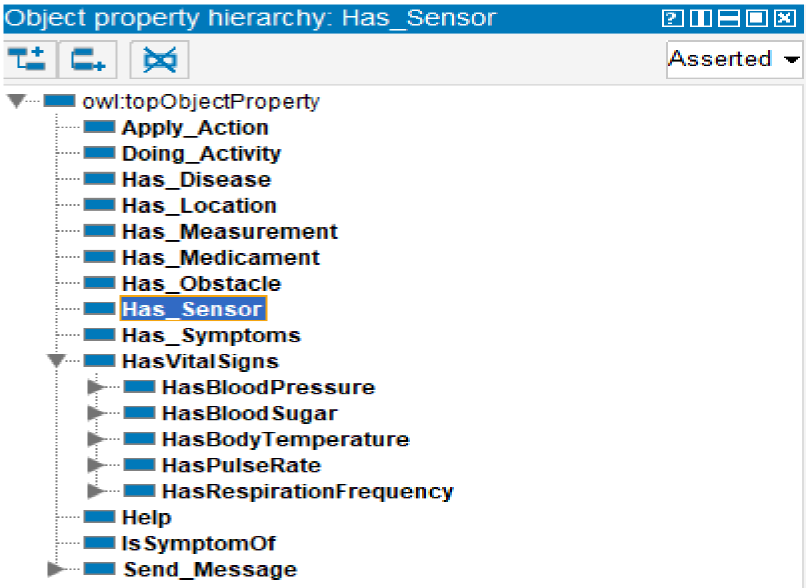

Figure 3.5: Object property hierarchy on the protègè-2000 platform

The data properties creation is represented in the figure 3.6 below:

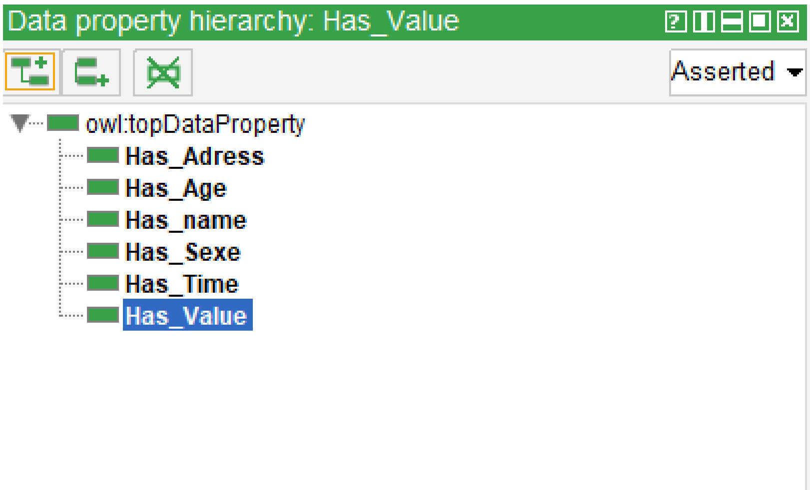

Figure 3.6: Data properties creation on the protègè-2000 platform

Some individuals (instances) are represented in figure 3.7 below:

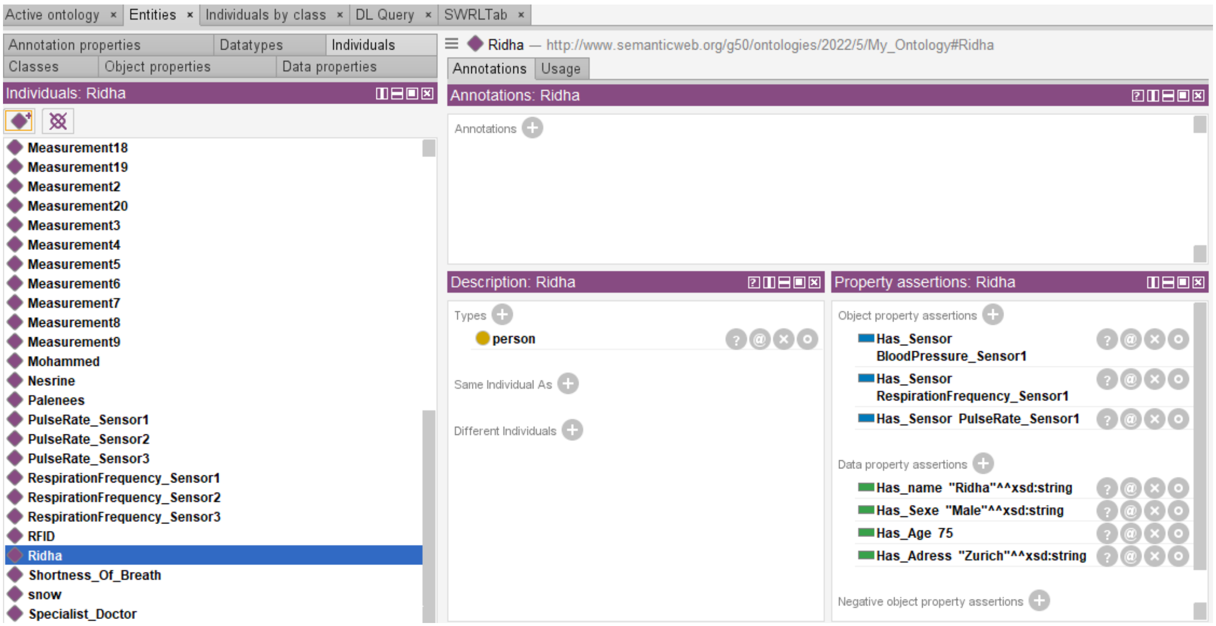

Figure 3.7: Individual (Instances) creation on protègè-2000 platform

4. Importing the ontological model:

Via the **'Owlready2'** library, we can import the ontology of the present working while typing below instruction:

```
from owlready2 import *
onto = get_ontology("Ontology_pfe.owl").load()
```

Figure 3.7: Importing the ontological mode by using Owlready2

5. SWRL rules :

Some rules forming the knowledge base captured from the Protégé platform are shown in the following figure 3.8:

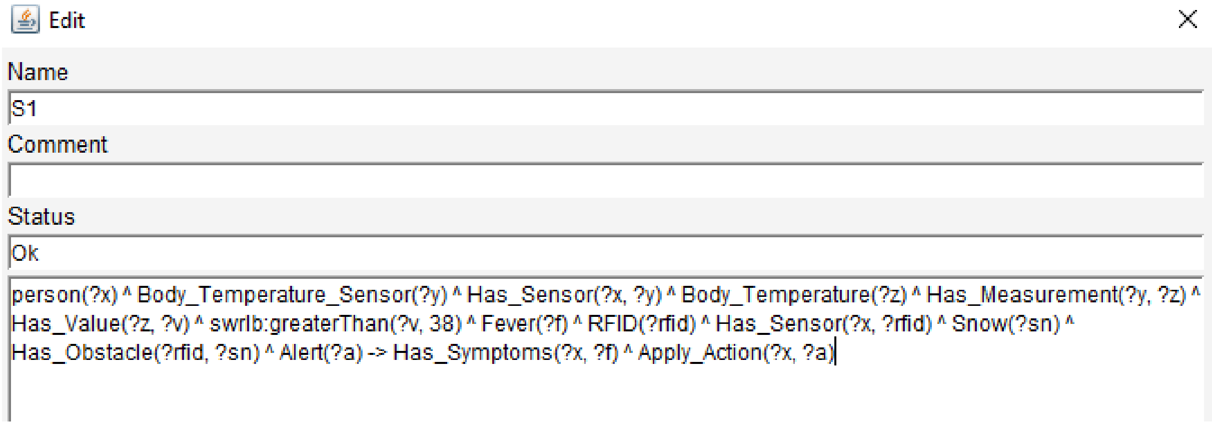

Figure 3.8: SWRL rule_1

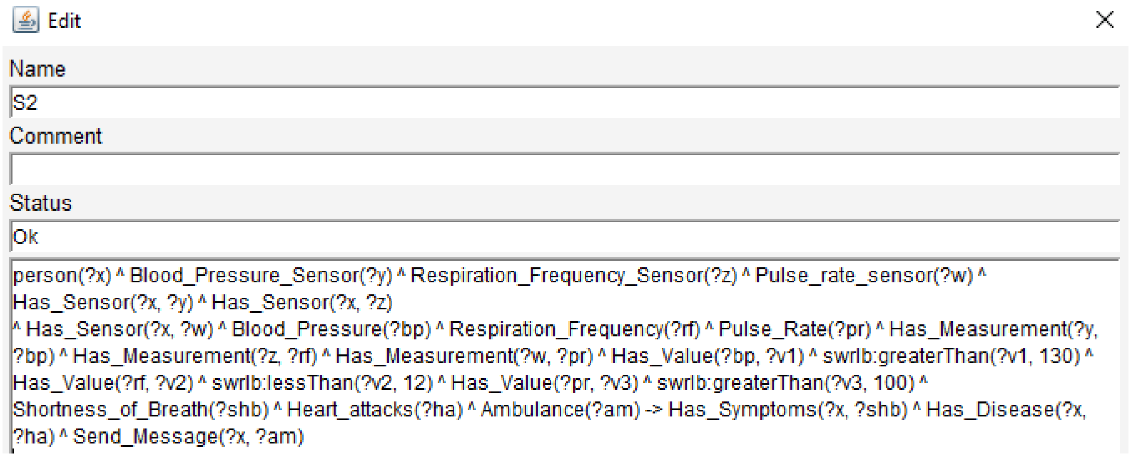

Figure 3.9: SWRL rule_2

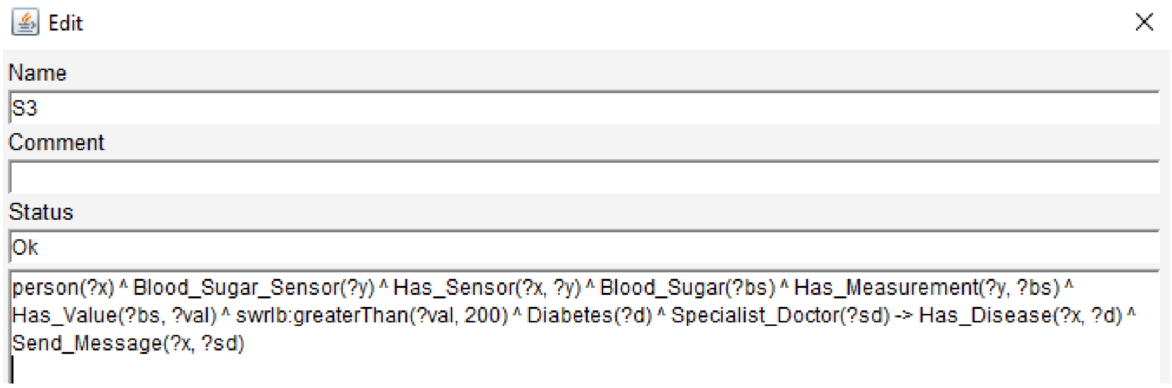

Figure 3.10: SWRL rule_3

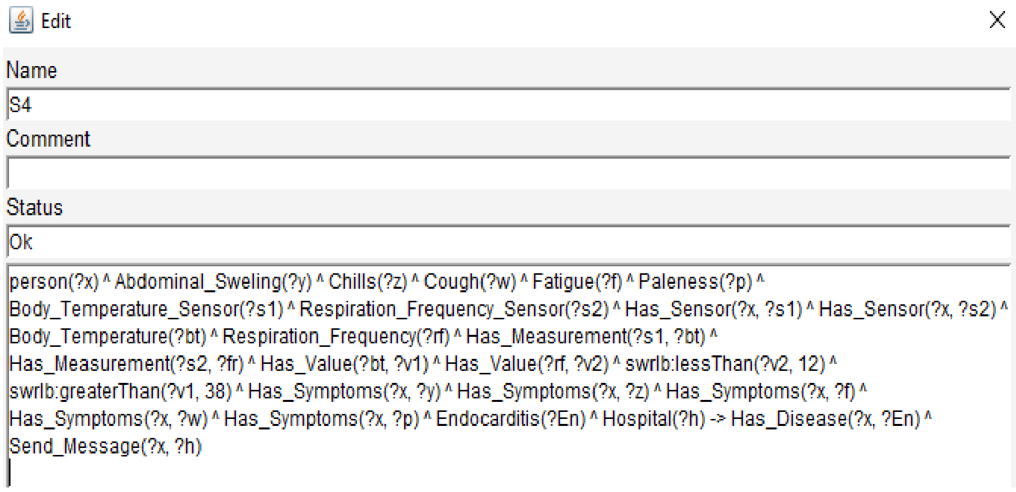

Figure 3.11: SWRL rule_4

6. How the system operate

- ✓ Creation of different individuals (instances) from different classes (concepts) as a knowledge base. For example some individuals from person class created as the targeted persons of our system, Where each person is defined by the name, age, sex and the address, Then other individuals from vital signs, sensors, and other concepts are created as it show in the figure below:

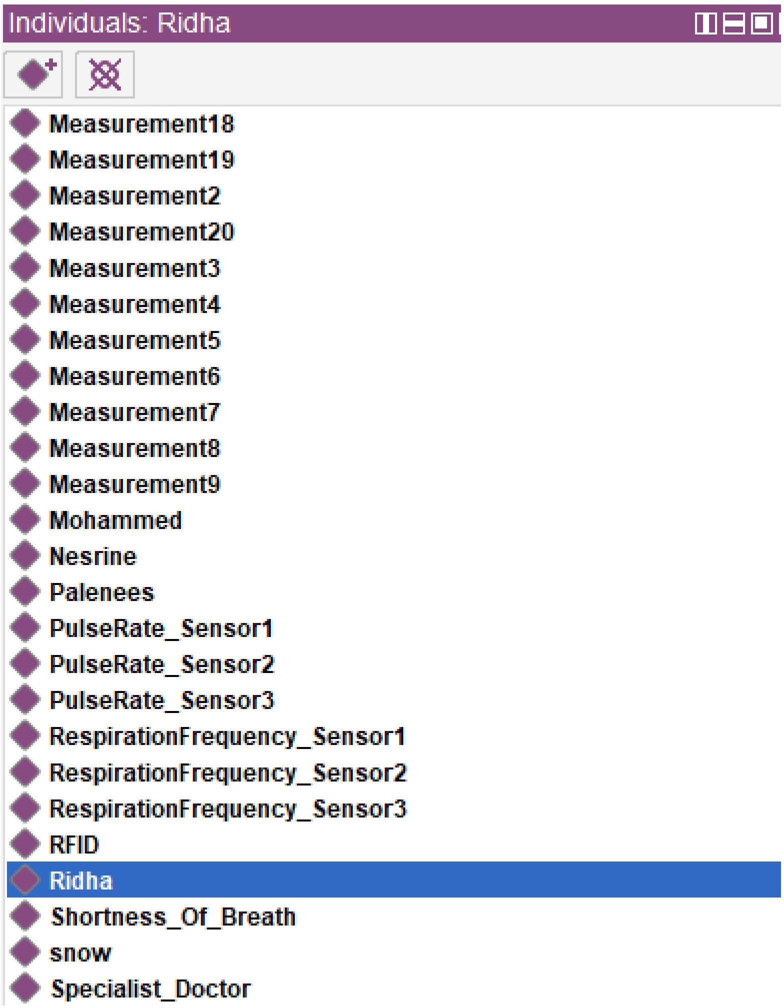

Figure 3.12: Individuals from different concepts creation

- ✓ As a second step, we have to create relations between individual, for example between the individual from class person and individual from class sensors, the relationship Has_Sensor is created as it shown in the figure below:

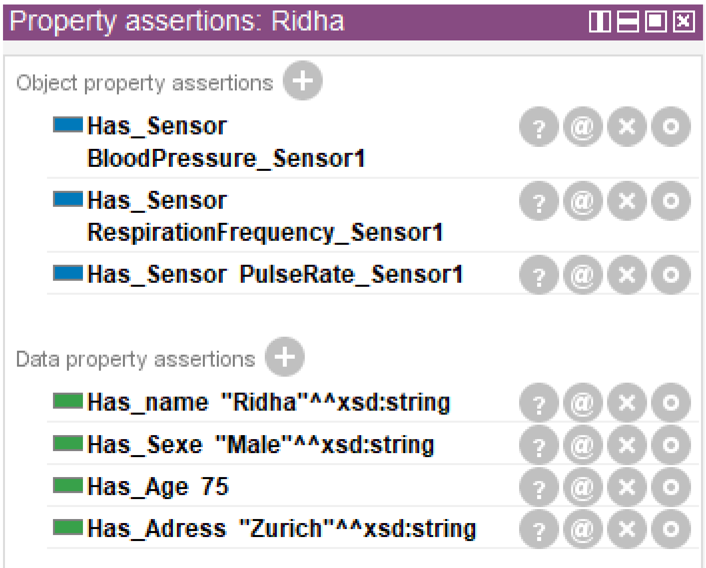

Figure 3.13: Relationships between two different individuals creation

- ✓ Rules will be applied later on the created knowledge base, rules are shown in the previous figures.

- ✓ by a click on the reasoner button, The system will create new knowledges, and they will be added to the knowledge base and based on these new knowledges the targeted person who is in need will get the appropriate assistance or the appropriate alert to avoid any danger. As it shown in the figures below which represents the results of the previous rules where the yellow color represents the new added knowledges:

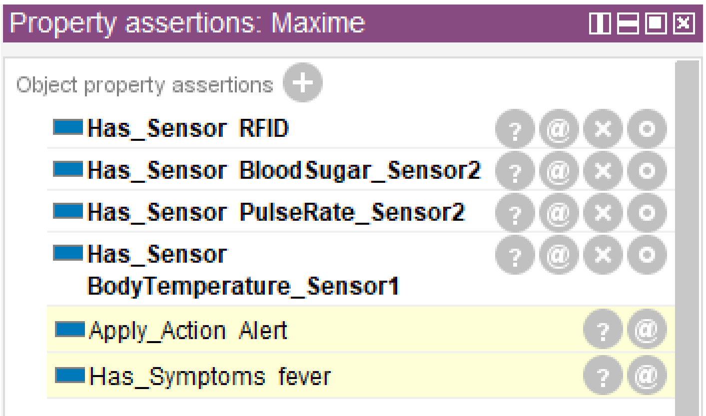

Figure 3.14: Rule'S 1 result

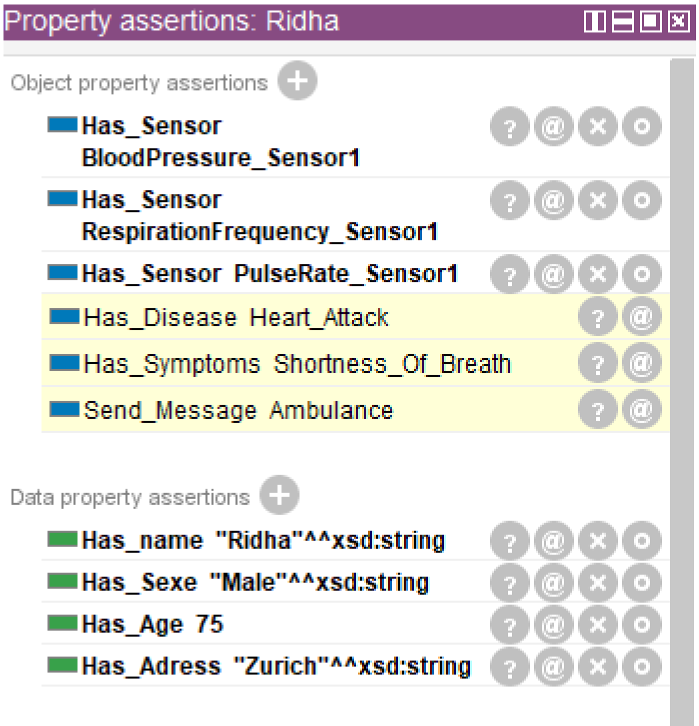

Figure 3.15: Rule2'S result

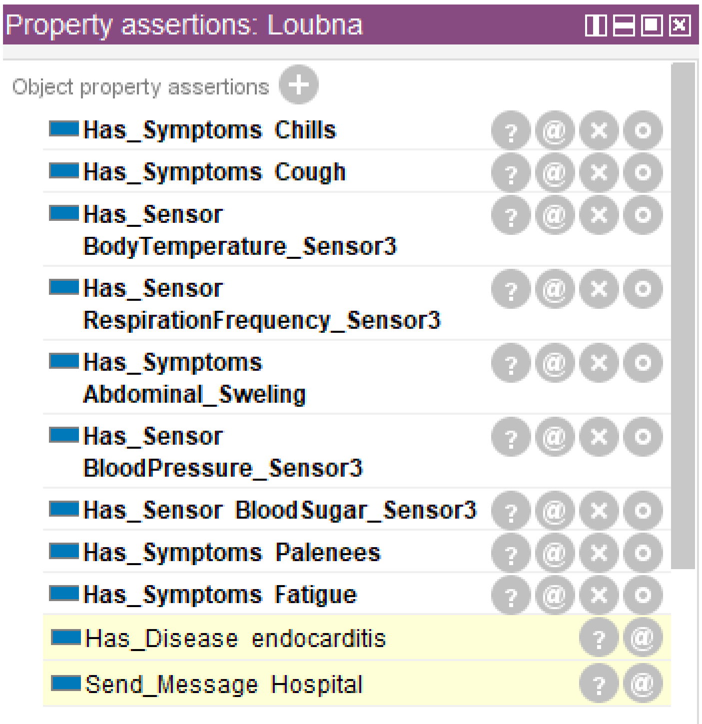

Figure 3.16: Rule3'S result

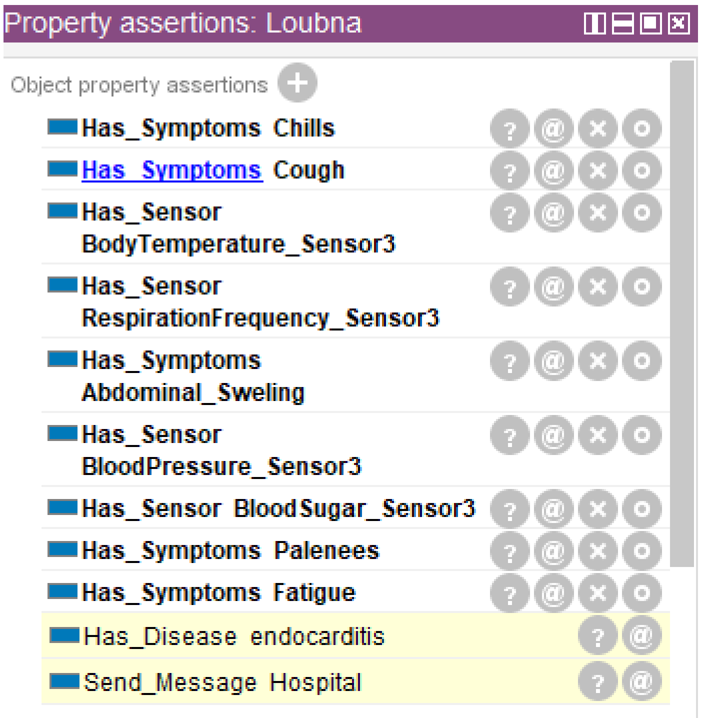

Figure 3.17: Rule'S 4 result

7. Conclusion

In this chapter we have seen some functionalities of the system based on the combination of the Internet of Things and Semantic Web technologies in order to guarantee better interoperability and by its role will provide technical assistance to people in situation of need.

General Conclusion

The work carried out during this end of study project was based on the combination between two disciplines which are: Internet of Things and Semantic Web or on what is called Semantic Web of Things In this context, we started first with a bibliographic study on the two fields mentioned above while dening their bases and concepts and the related works based on the approach that we will use. Subsequently, we presented the stages of the design of the system while being based on the ontological model which comprises the concepts, the relations, the rules and the requests by the Protégé-2000 tool in order to make recommendations that make life easier for people who are in need as the elderly for example.

Following the work carried out, some perspectives can be given:

- ✓ Evaluation of the ontology created by the experts of the domain or by the persons concerned (those who are in need).
- ✓ The actual use of IoT tools to obtain more concrete and meaningful results.

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[3]: Caractéristiques de l'Internet des objets, https://fr.acervolima.com/caracteristiques-de-l-internet-des-objets/ (view on 28/04/2022).

[4]: IoT Explained – How Does an IoT System Actually Work, https://www.leverege.com/blogpost/iot-explained-how-does-an-iot-system-actually-work (view on 28/04/2022).

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