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# Master Thesis

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**Option**:

Science and technology of information and communication

# Theme

## Fuzzy logic-based approach using semantic IoT to assist elderly and people with disability


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# ABSTRACT

Millions of the elderly and people with disabilities around the world suffer from difficulties in carrying out their daily life tasks. However, thanks to the continuous technological development that affected all fields, including the medical one, it became possible to integrate them in a greater way into society and facilitate their lives, even partially. To do this, in this project we took advantage of the Internet of Things technology (iot) to collect measuerments of their vital signs through various sensors, and to gain interoperability, we needed semantic web to make the data more understandable to the machines, by using many of its technologies (ontology, SWRL, etc). We also used fuzzy logic in an effective way to resolve disputes and uncertinty and for better evaluation of options. The combination of these disciplines and technologies produces an ontological model for us that contains various informations about the target person (type of disability, vital signs, objectives and healthcare services he needs, etc.) to facilitate doctors' follow-up to them and make their life easier.

**Keywords:** Internet of Things, Semantic Web, Ontology, Fuzzy logic, People with disabilities, Elderly, SWRL, interoperability.

# Résumé

Des millions de personnes âgées et de personnes handicapées dans le monde souffrent de difficultés dans l'accomplissement de leurs tâches quotidiennes. Cependant, grâce au développement technologique continu qui a touché tous les domaines, y compris le médical, il est devenu possible de les intégrer davantage dans la société et de leur faciliter la vie, même partiellement. Pour ce faire, dans ce projet, nous avons profité de la technologie Internet des objets (iot) pour collecter des mesures de leurs signes vitaux à travers différents capteurs, et pour gagner en interopérabilité, nous avions besoin du web sémantique pour rendre les données plus compréhensibles pour les machines, en utilisant plusieurs de ses technologies (ontologie, SWRL, etc). Nous avons également utilisé la logique floue de manière efficace pour résoudre les conflits et les incertitudes et pour une meilleure évaluation des options. La combinaison de ces disciplines et technologies produit pour nous un modèle ontologique qui contient diverses informations sur la personne cible (type de handicap, signes vitaux, objectifs et services de santé dont elle a besoin, etc.) pour faciliter son suivi par les médecins et faire leur vie plus facile.

**Mots-clés:** Internet des objets, Web sémantique, Ontologie, Logique floue, Personnes handicapées, Personnes âgées, SWRL, interopérabilité.

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# General Introduction

Internet of things technology has imposed itself on the technical and technological scene strongly, as it allows receiving and sending huge amount of data from various sources and through various devices connected to the Internet. Due to the huge amount of data, we can easily fall into the problem of data interoperability, and for this we use semantic web, which allows the processing of this data easily, and without human intervention by using her different technologies such us SPARQL and SWRL. In this project, we aim to improve semantic reasoning by using a new structure that contains fuzzy logic, and the solution is applied in healthcare field for the benefit of elderly and persons with disabilities in order to reduce as much as possible the obstacles they face in carrying out their daily activities. This master thesis consisting of: Abstract, General introduction and four chapters:

**Chapter 1 “State of the art”:** We present in this chapter the defintions of the elderly and people with disabilities and the challenges they face, we also present and discuss the two discplines of Internet of Things and semantic web.

**Chapter 2 “Fuzzy logic**”: We present in this chapter the main concepts and defintions of fuzzy logic and we discuss the related works.

**Chapter 3 “Conception”:** We present in this chapter the architecture of our system with explanation.

**Chapter 4 “Implementation”:** We present in this chapter the main parts of our code and also the results.

In the end we make General conclusion about our system and our perspectives.

# Chapter 1

# State of the art

## 1.1 Introduction

The category of the elderly and persons with disabilities is a group with an important role in society, as it constitutes a significant segment, but it still suffers from not being properly highlighted. In this context, we will discuss them in this chapter, and we will talk about their types and the problems they encounter in their daily activities. Also, we will discuss how we will use the technologies of the semantic web and the internet of things to facilitate their daily life tasks.

## 1.2 Definitions of The Elderly and People with disabilities

(Sabharwal et al., 2015) says that in medical studies, someone is considered elderly if they are 65 or older.

And according to (Shakespeare, 1999) People who are disabled are those whose level of physical, sensory, or mental impairment is significant enough to significantly interfere with their day-to-day activities.

### 1.2.1 Types of disabilities

According to (Shakespeare, 1999) there is 3 types of disabilities which are:

- Sensory disability.
- Mental disability.
- Physical disability.

### 1.2.2 Common challenges facing elderly and people with disability

The elderly and people with disabilities face many challenges in their daily lives.

These are some of the common challenges that they face:

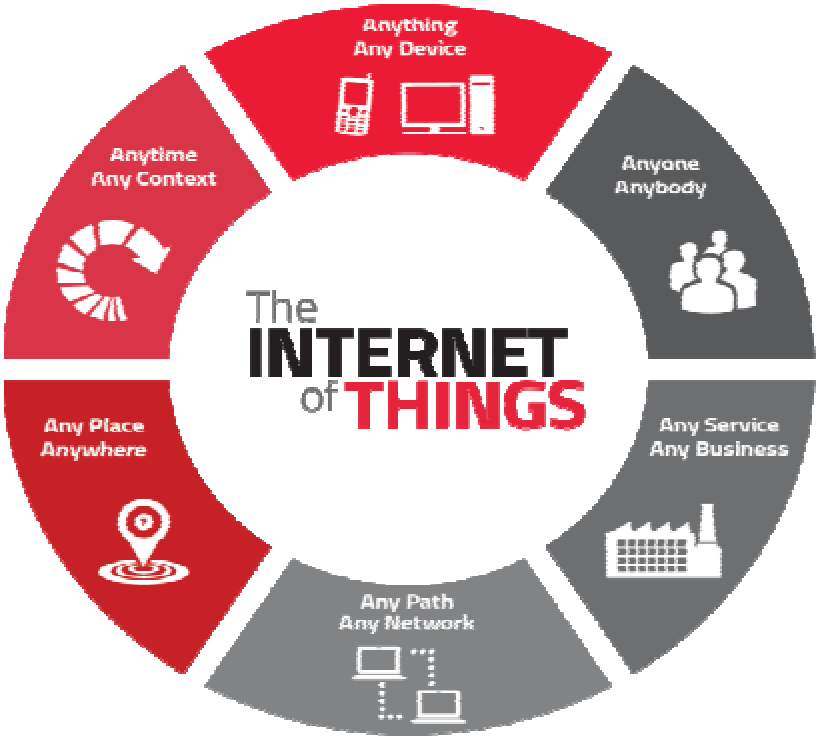
- Daily actions like dressing, eating, getting out of bed, etc.
- Communication with others.
- Shopping.
- Travelling.
- Studying.
- Finding a job.
- The aggression shown against them.
- The lack of respect, representation and consideration.

### 1.2.3 Technologies to help the elderly and people with disabilities

The continuous technological development has facilitated the lives of the elderly and people with disabilities by reducing the challenges they face daily. In this section, we will discuss two disciplines, which are the Internet of Things and the Semantic Web, that we are going to use to solve those problems.

## 1.3 Internet Of Things

According to (Patel et al., 2016) The Internet of Things (IOT) is a network of physical items, according to the commonly used definition. The internet has developed into a network of devices of all types and sizes, including cars, smart phones, home appliances, toys, cameras, medical equipment, industrial systems, animals, people, and buildings. These devices are all connected, communicating, and sharing information in accordance with predetermined protocols in order to achieve smart reorganizations, positioning, tracing, safety and control, and even real-time online monitoring and online upgrades for individual users.




. Figure 1.1: Internet of things (Patel et al., 2016)

### 1.3.1 Enabling technologies for IoT

According to (Patel et al., 2016) The Internet of Things (IoT) is a worldwide infrastructure for the information society that connects (physical and virtual) objects using existing and developing interoperable information and communication technologies to enable improved services.

Through the Internet of Things, communication is expanded to include everything around us. More than only machine-to-machine communication, wireless sensor networks, sensor networks, 2G/3G/4G,GSM,GPRS,RFID, WI-FI, GPS, microcontroller, and microprocessor, among other technologies, the Internet of Things encompasses a wide range of other applications. These are regarded as being the "Internet of Things" applications' enabling technology.


Figure 1.2: Internet of things: Enabling technology (Patel et al., 2016)

## 1.3.2 Characteristics of IoT

According to (Patel et al., 2016) the following are the IoT's core characteristics:

**Interconnectivity:** Everything can be connected to the global information and communication infrastructure in terms of the Internet of Things (IoT).

**Things-related services**: The Internet of Things (IoT) is capable of offering services related to things within the bounds of things, such as privacy protection and semantic consistency between real and associated virtual objects. Both the technology in the physical world and the information world will alter in order to provide thing-related services within the limitations of things.

**Heterogeneity:** Devices in the Internet of Things are heterogeneous since they are based on several hardware platforms and networks. Through multiple networks, they can communicate with other gadgets or service platforms.

**Dynamic changes:** The context of devices, such as location and speed, as well as their states, such as sleeping and waking up, connected and/or disconnected, vary dynamically. Additionally, the quantity of devices may fluctuate.

**Enormous scale:** Compared to the number of devices currently linked to the Internet, the number of devices that will need to be managed and that will be able to communicate with one another will be at least an order of magnitude more.

The management of the generated data and its interpretation for application purposes will be even more crucial. This has to do with both the semantics of data and effective data processing.

**Safety:** Safety must not be overlooked as we reap the rewards of the IoT. We must design for safety as both the IoT's producers and users. This covers the security of our private information as well as the security of our physical safety. In order to secure endpoints, networks, and the data passing across them all, a scalable security paradigm must be developed.

**Connectivity:** Network compatibility and accessibility are made possible via connectivity. Accessibility involves joining a network, whereas compatibility gives everyone the same ability to use and create data.

### 1.3.3 Architecture of IoT

According to (Patel et al., 2016) IOT architecture is made up of numerous layers of supporting technology. It is used to describe the interrelationships between multiple technologies as well as the scalability, modularity, and configuration of IOT deployments in various scenarios. IOT's detailed design is shown in Figure 1.3. Below is a description of each layer's functionality:

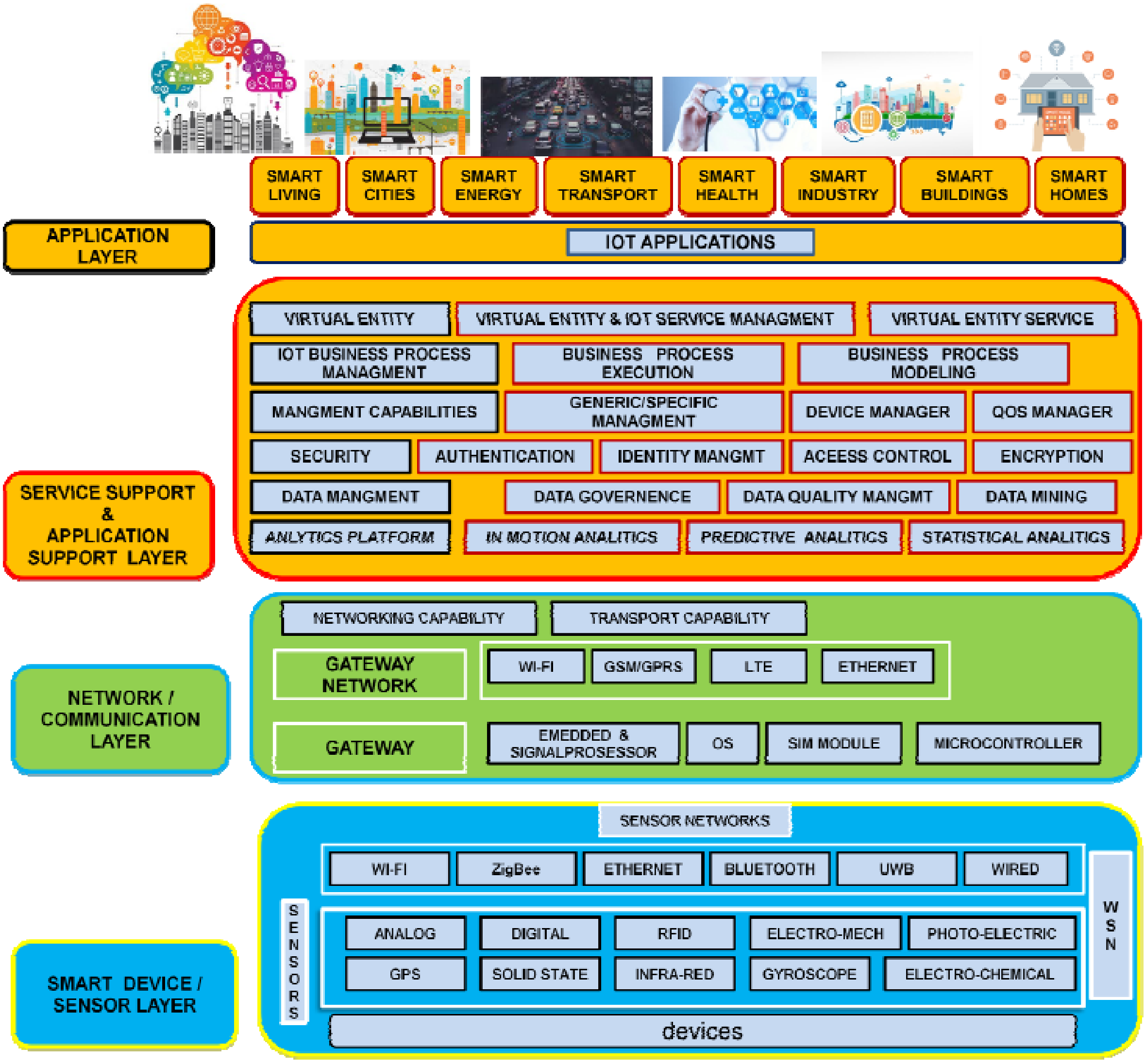



Figure 1.3: IOT Architecture (Patel et al., 2016)

**Smart device / sensor layer:** Sensor-integrated smart items make up the lowest layer. The sensors facilitate the connection between the physical and digital worlds, enabling the collection and processing of real-time data. Different types of sensors are available for diverse uses. The sensors may monitor things like temperature, air quality, speed, humidity, pressure, flow, movement, and electricity, among other things. They may occasionally additionally contain some memory, allowing them to store a set amount of measurements. A sensor can take a reading of the physical attribute and turn it into a signal that an instrument can decipher. According to their specific function, sensors are categorized into categories including environmental sensors, body sensors, home appliance sensors, and car telematics sensors, among others.

**Gateways and Networks:** These tiny sensors will generate enormous amounts of data, which calls for a reliable and high-performance wired or wireless network infrastructure as a transport medium. Machine-to-machine (M2M) networks and their associated applications have been supported by current networks, which are frequently linked with highly dissimilar protocols. The need to support a greater range of IOT services and applications, including high-speed transactional services, context-aware apps, etc., necessitates the use of several networks with different technologies and access protocols that can cooperate with one another. These networks, which fulfill the communication requirements for latency, bandwidth, or security, might take the shape of private, public, or hybrid networks. Various gateway networks (WI-FI, GSM, GPRS), microcontrollers, and processors, etc.

**Management Service Layer:** Through analytics, security measures, process modeling, and device management, the management service makes information processing possible.

**Application Layer:** The Internet of Things (IoT) application includes "smart" settings and spaces in a variety of fields, including: transportation, buildings, cities, lifestyle, retail, agriculture, factories, supply chains, emergencies, healthcare, user interaction, culture and tourism, environment, and energy.

## 1.3.4 Application areas of IoT

According to (Patel et al., 2016) The Internet of Things has a wide range of potential uses that might affect almost every aspect of daily life for people, businesses, and society at large. The Internet of Things (IoT) application includes "smart" settings and spaces in a variety of fields, including: transportation, buildings, cities, lifestyle, retail, agriculture, factories, supply chains, emergencies, healthcare, user interaction, culture and tourism, environment, and energy. Some IOT applications are shown in figure 1.4 below:

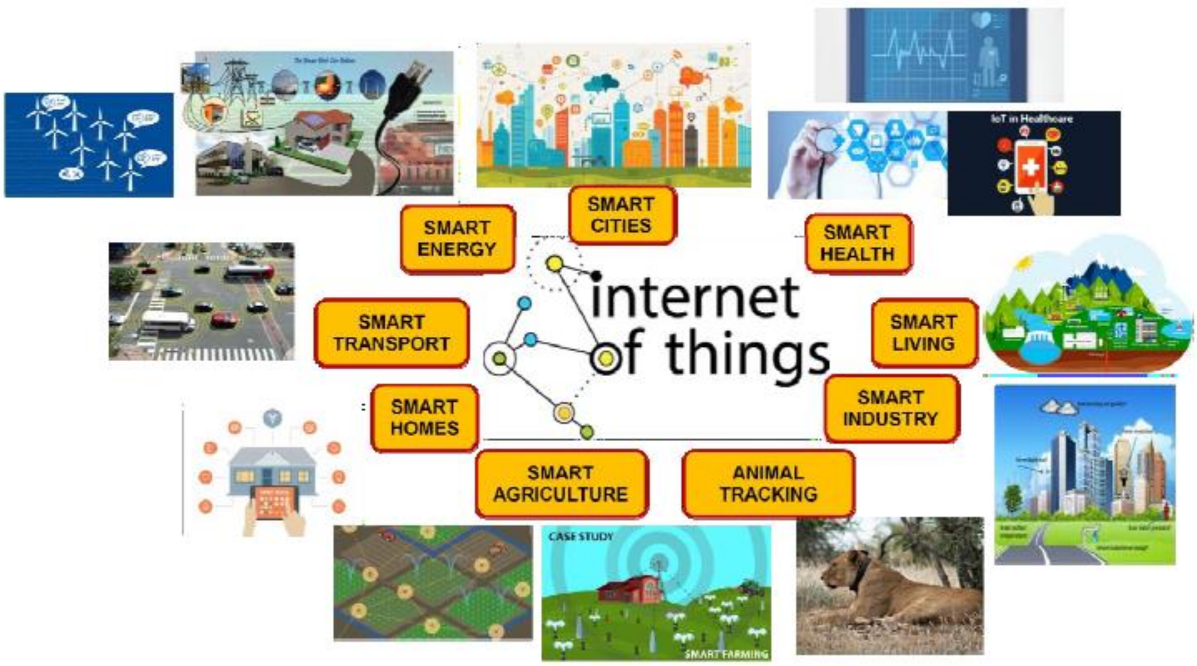



Figure 1.3: IoT Applications (Patel et al., 2016)

## 1.3.5 Future challenges for IoT

According to (Patel et al., 2016) Before IOT may be widely adopted, there are important issues and ramifications that must be resolved:

**Interoperability:** Interoperability is the most fundamental core property of the traditional Internet; the first prerequisite for internet connectivity is that "connected" devices be able to "talk the same language" of protocols and encodings. Different standards are used nowadays by various sectors to support their applications. The usage of standardized interfaces between these various entities becomes crucial when there are many data sources and heterogeneous devices involved. This is especially true for applications that support boundaries between different systems and across organizational boundaries. IOT systems must therefore manage a high level of interoperability.

**Security and Privacy:** We must effectively address trust and security functions as the IoT becomes a fundamental component of the Future Internet and is used for large-scale, partially mission-critical systems. New issues with reliability, privacy, and trust include:

• supplying reliable information that can be trusted in shared information models to support reuse across numerous applications.

• Enabling the safe transfer of data between Internet of Things devices and users of their data.

• Including safety measures for devices that are susceptible.

**Cost versus Usability:** IOT employs technology to link real-world devices to the web. The cost of the components required to support features like sensing, tracking, and control mechanisms must be relatively low in the upcoming years for IOT usage to increase.

**Data Management:** An essential component of the Internet of Things is data management. The amount of data generated and the procedures involved in handling that data become crucial when taking into account a world of networked items that are continually exchanging all forms of information.

**Device Level Energy Issues:** Given that communication is the task that consumes the most energy on devices, interconnecting "things" in an interoperable manner while taking energy limits into consideration is one of the key problems in IoT.

- And because of this challenges and especially the major one : interoperability, we will call upon to the semantic web in the next section.

## 1.4 Semantic web

According to (Berners-Lee et al., 2001) The Semantic Web is an extension of the current Web, not a distinct one, where information is given a clear meaning to improve cooperation between computers and people.

### 1.4.1 Ontology

According to (O'Hara et al., 2009) the ontology is a crucial component for SW applications. Ontologies are shared conceptualizations of a domain that are designed to make it easier for people to share knowledge and information by coordinating vocabulary and enabling simple inferences about an object's qualities and inheritance.

And according to (Reyes-Pena et al., 2019) the elements of the ontology are:

**- Concepts (classes):** The primary codified components of the domain are concepts. Due to the logic, certain properties that must be met by the concepts can be used to describe them.

**- Relationships:** are ties between the concepts used to express the taxonomic or non taxonomic ontology structure.

**- Functions:** are components whose sole job is to gather data from other components.

**- Instances (objects):** According to ontology structure, instances (or objects) are representations of the primary objects inside a domain.

**- Axioms:** are the limitations, guidelines, and definitions of logic correspondences that must be followed in the interaction between ontology elements. The smallest unit of knowledge within an ontology is represented by the axioms.

The figure below is an example of ontology:

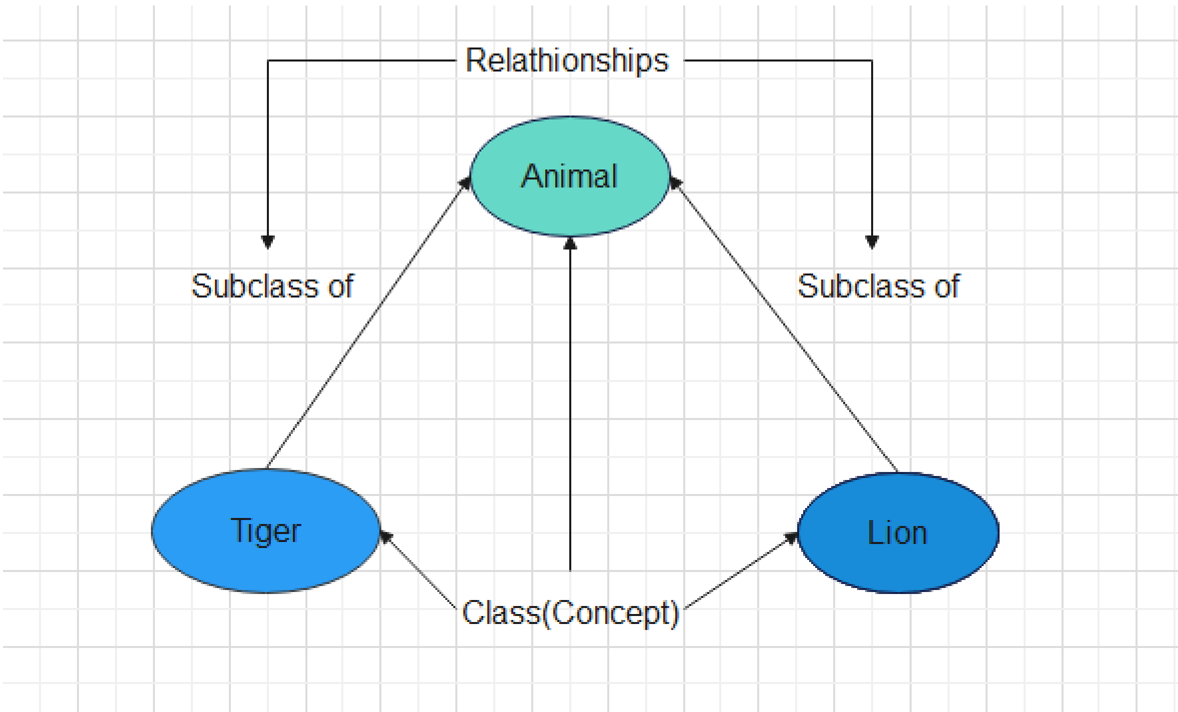



Figure 1.4: Example of an ontology

### 1.4.2 Semantic web Stack

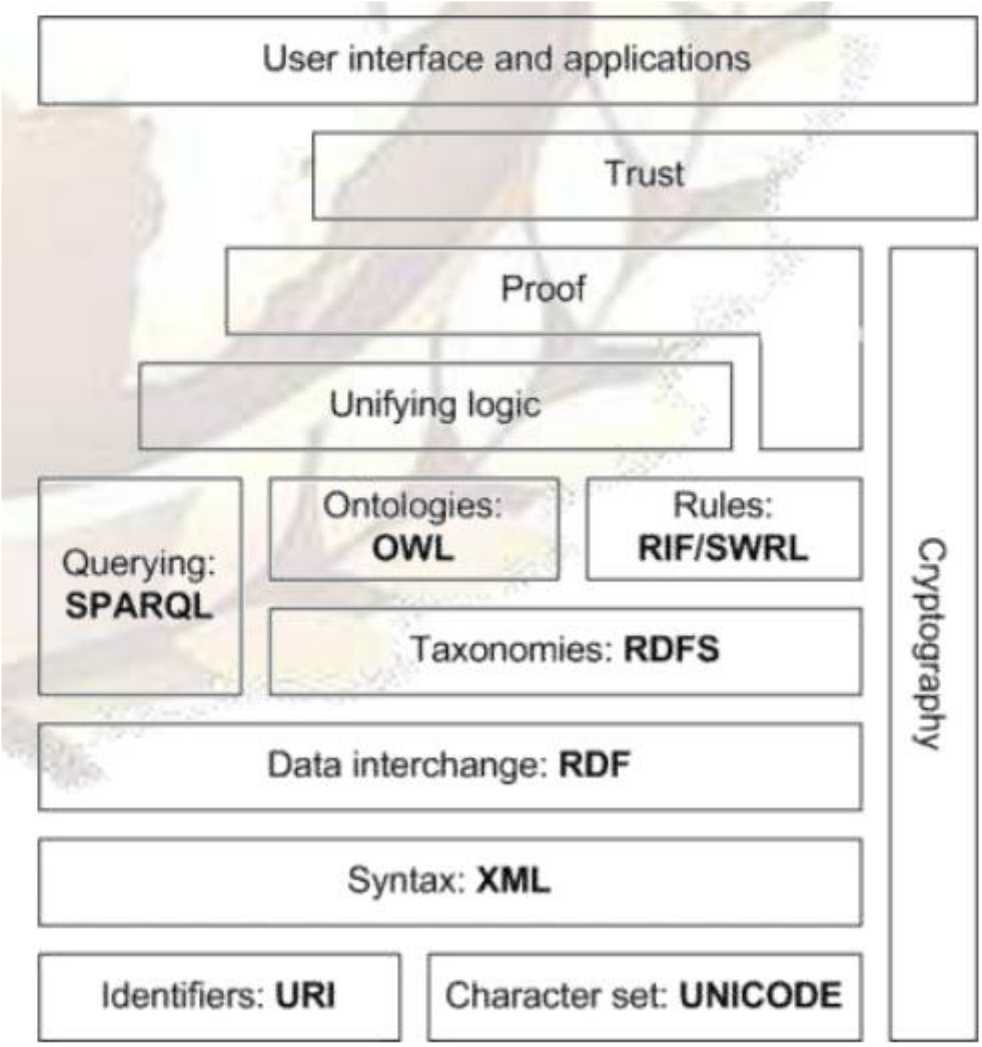



Figure 1.5: Semantic Web Stack-A layered approach (Pandey et al., 2012)

According to (Pandey et al., 2012) there is 8 layers in semantic web stack which are:

**Layer 1: URI and Unicode**

Any character written in any language must be encoded at the lowest layer, which is also in charge of uniquely identifying various resources. By utilizing Unicode and URIs (Uniform Resource Identifiers), this layer standardized the text.

Unicode is used to alter and represent text in numerous languages. Semantic Web facilitates the linking of documents written in various human languages.

**Layer 2: XML**

On the internet, interoperability is accomplished using XML. This layer serves as a foundation for combining pieces from many vocabularies to perform a particular function. Although XML offers a basic vocabulary for structuring content within documents, it does not assign any semantics to the content's meaning. The majority of Semantic Web technologies do not now require XML as a component because alternative syntaxes, such Turtle, exist. Although it has not gone through a formal standardization procedure, Turtle is a de facto standard.

**Layer 3: RDF**

The foundational internet technologies make up the first two levels. The genuine Semantic Web begins at this layer.

The W3C standard for characterizing Web resources is the Resource Description Framework (RDF). XML is used to write RDF. RDF is not intended to be presented to humans; rather, it is meant to be read and understood by computers.

For defining data models, which refer to objects (or "resources") and their relationships, RDF provides a straightforward language. There are several different syntaxes that can be used to represent an RDF-based model, including RDF/XML, N3, Turtle, and RDFa. The Semantic Web's foundational standard, RDF, is supported by W3C.

With semantics for generalized-hierarchies of such attributes and classes, RDF Schema (RDFS), an extension of RDF, is a vocabulary for expressing properties and classes of RDF-based resources.

**Layer 4: The Ontology layer**

In ontology, things are precisely described together with their connections. Sometimes the RDFS definition for a specific Web resource is insufficient, in which case a larger ontological vocabulary is required.

Web ontology Language, or OWL, is a language for handling web data. A W3C standard governs it. Three sublanguages of OWL exist:

- OWL Fall
- OWL Lite
- OWL DL (Description Logic)

OWL expands the language used to describe properties and classes, including enumerated classes, deeper property type, cardinality (e.g., "exactly one"), equality, and relations between classes (e.g., disjointness).

However, despite the similarities between RDF and OWL, OWL is a more powerful language with better machine interpretability, a wider vocabulary, and stronger syntax than RDF.

A protocol and query language for Semantic Web data sources is called SPARQL (Simple Protocol and RDF Query Language). It is possible to query any RDF-based data (statements including RDFS and OWL) using the RDF query language SPARQL.

W3C recommends RIF (Rule Interchange Format). SWRL (Semantic Web Rule Language) is a proposed Semantic Web rules language that combines OWL (OWL DL + OWL Lite) sublanguages.

Rules assistance will come from RIF or SWRL. This is crucial, for instance, to enable the description of relations that cannot be directly stated using OWL's description logic.

**Layer 5: The Logic layer**

A logic layer is necessary for the expression of rules. This layer is applied to further improve ontology language.

**Layer 6: The Proof layer**

Both the actual deductive procedure and the representation of proofs in Web languages are involved. In Tim Berner-Lee's vision, the Semantic Web does not include the creation of proofs. The reason is that it is impossible to standardize the production of proofs, which is still a very active area of research. Only proofs should require verification by a semantic web engine. In the event that someone sends site X a proof of authorization to use the site, site X must be able to confirm that proof. A appropriate inference engine accomplishes this.

**Layer 7: The Trust layer**

The Semantic Web is unimaginable without trust. There is nothing left to do but discard the information if company A provides information to company B but there is no way for B to know that this information truly originated from A or that A can be trusted. For this, digital signatures may be utilized. By confirming that the premises come from a reliable source and relying on formal logic when deriving additional information, trust in derived statements will be supported.

**Layer 8: The UI and Application layer**

The final layer that allows humans to access Semantic Web applications is the UI (User Interface).

### 1.4.3 Additional Factor in Semantic Web Development

**REASONERS:** According to (O'Hara et al., 2009): Reasoning is more complex in the Semantic Web (SW) than it was in earlier technologies. In order to infer the outcomes of a collection of claims that have been ontologically interpreted, the area of SW reasoning has been the subject of extensive research. In this situation, inference rules must have explicit semantics and be able to handle the scattered and diversified nature of the SW.

- Some of the most famous of these reasoners are:

- Pellet
- HermiT
- FaCT++

### 1.4.4 Application Areas for semantic web

There are many applications areas for semantic web some of them According to (O'Hara et al., 2009) are:

E-science, the data-driven, computationally demanding pursuit of science in massively distributed computer settings, is the most significant application for SW technology. Analyses and experiments in fields like particle physics, meteorology, and the life sciences generate enormous amounts of data.

Another potentially significant application area where information is extensively disseminated but is highly heterogeneous is e-government. Government information can come from different levels of government and can vary in provenance, confidentiality, and "shelf life" (some information will last for decades or even centuries, while other information may become outdated within hours). It is obvious that integrating that knowledge quickly is a significant problem.

### 1.4.5 Semantic web of things

According to (Chatzimichail et al., 2021) The Semantic Web of Things (SWoT) is an extension of the World Wide Web that aims to address issues brought on by heterogeneous systems and improve knowledge of various IoT sectors. The basic goal of the Web of Things is to make IoT systems and application domains interoperable. The WoT's overall goal is to support and supplement current IoT standards and solutions.

### 1.4.6 Features of Semantic web extends with IoT

According to (Chatzimichail et al., 2021) to realize the SWoT researchers' extension of the IoT with all the exceptional properties of SemanticWeb:

-make extensive use of URIs and HTTP,

-utilizing interoperable references to connect domain models,

-the use of widely used standard languages,

-Extrapolation of logical sequences to achieve domain expressiveness.

### 1.4.7 SWoT’s challenges

According to (Chatzimichail et al., 2021) they are:

-steadily expanding IoT ecosystems with several unique gadgets;

-the capacity to connect gadgets made by various manufacturers;

-Open source developers' capacity to create software for IoT contexts;

-create programs for general domains that make use of sensor data.

## 1.5 Conclusion

At the end of this chapter, we have presented the most related concepts of the elderly and people with disabilities and we have discussed the disciplines of iot and semantic web, their concepts, architecture, etc. In the following chapter we will discuss the approach of fuzzy logic and how it can enhance decisions for the elderly and people with disabilities.

# Chapter 2

# Fuzzy logic

## 2.1 Introduction

As mentioned before in the first chapter, we will discuss the approach of fuzzy logic for enhancing decisions, therefore the elderly and people with disabilities can have easier life and can integrate more with society. We will talk about the main concepts, definitions and the inference system.

## 2.2 Fuzzy logic

According to (Dernoncourt et al., 2013) that In 1965, Lotfi Zadeh developed fuzzy logic as an expansion of Boolean logic based on the mathematical theory of fuzzy sets, which is a generalization of the traditional set theory. Fuzzy logic offers a very useful flexibility for thinking that makes it possible to take into account errors and uncertainties by incorporating the notion of degree in the verification of a condition. This allows a condition to be in a state other than true or false.

The rules of fuzzy logic are set in plain language, which is a benefit for formalizing human reasoning.

## 2.3 Concepts and definitions

### 2.3.1 Fuzzy sets

According to (Dernoncourt et al., 2013) The theory of fuzzy sets, which is a generalization of the classical set theory, serves as the foundation for fuzzy logic. The classical set theory is a specific instance of fuzzy sets theory, which may be understood by saying that it is a generalization of the former. The classical set theory is a subset of the theory of fuzzy sets, to use a set theory metaphor.

The figure below shows the difrence between Crisp set and Fuzzy set:

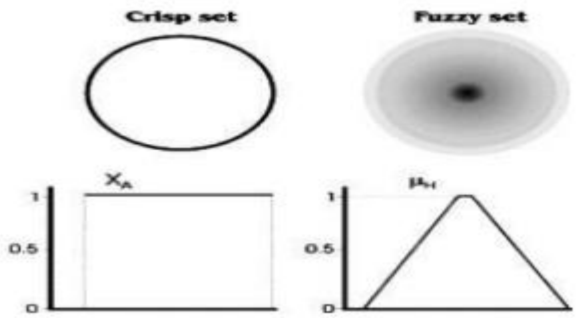



Figure 2.1: Crisp set vs. Fuzzy set (Jain et al., 2020)

#### 2.3.1.1 Membership Functions

According to (Sadollah, 2018) The Membership Functions (MF) are the fundamental units of fuzzy set theory, and they are what determine how fuzzy a set is. Because they have an impact on a fuzzy inference system, MF shapes are crucial for a specific task. They could be triangular, trapezoidal, Gaussian, or any number of other shapes. Really, the sole prerequisite for an MF is that it must range between 0 and 1.

According to (Sabri et al., 2013) the membership functions define three standard regions. They are:

With membership values ranging from 0 to 1, the membership functions can be either symmetric or asymmetric.

**Core:** The components of the core are the items whose membership function is 1.

**Support:** The components in the support are those whose membership is larger than 0.

**Boundary**: Elements whose membership is between 0 and 1 make up the boundary.

The figure below shows the position of the three standard regions:

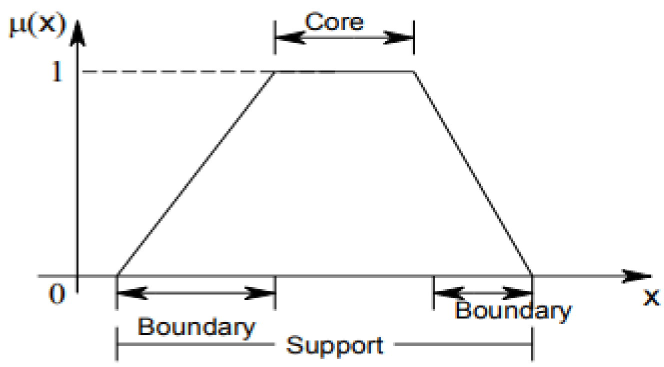



Figure 2.2: A typical FS with set parameters (Jain et al., 2020)

According to (Jain et al., 2020) this are some of the most known types of membership functions:

**Triangular Membership Function:**

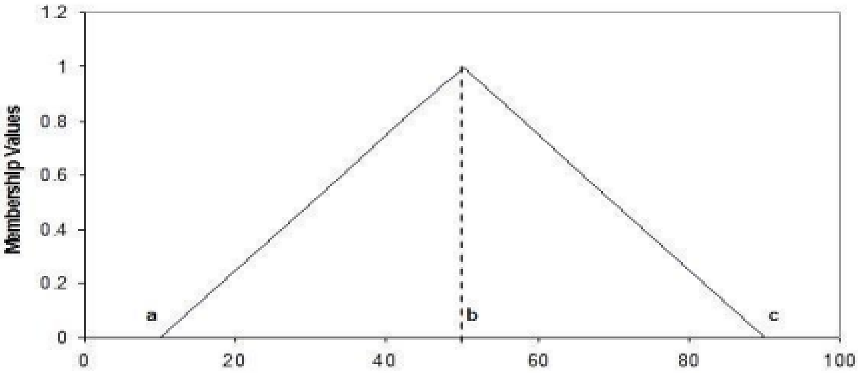



Figure 2.3: Triangular fuzzy MF (Jain et al., 2020)

**Trapezoidal MF:**

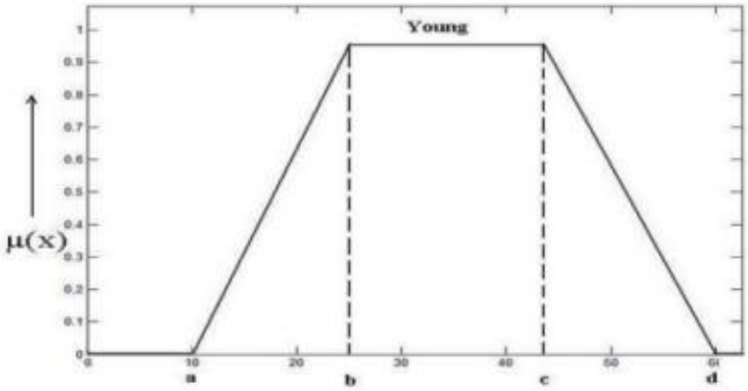



Figure 2.4: Trapezoidal MF (Jain et al., 2020)

**Gaussian MF:**

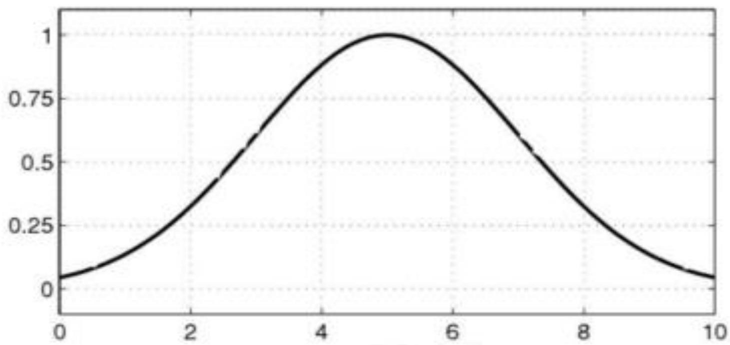



Figure 2.5: Gaussian MF (Jain et al., 2020)

### 2.3.1.2 Fuzzy variable

According to (Sabri et al., 2013) while variables in mathematics typically have numerical values, non-numeric linguistic variables are frequently utilized in fuzzy logic applications to simplify the explanation of rules and facts. The use of fuzzy variables enables computation using words rather than numbers. Linguistic variables have values that are words or phrases from the natural language.

#### 2.3.1.3 Fuzzy logic opearators

According to (Sabri et al., 2013) the binary logic operators intersection (AND), union (OR), and complement (NOT) are used in classical set theory.

Although fuzzy logic does not have a finite number of possible outcomes for each input, these operators nonetheless perform admirably for bivalent logic.

For all likely fuzzy values—specifically, all real numbers from 0 to 1—the operators must be written as functions.

#### 2.3.1.4 Fuzzy rules

According to (Sabri et al., 2013) a set of linguistic fuzzy rules often describe the dynamic behavior of a fuzzy system. These rules are linguistic "if-then" statements that make use of fuzzy logic, fuzzy inference, and fuzzy sets. These regulations are founded on the expertise and understanding of a human in that field.

A fuzzy rule's antecedent and consequent are assertions that comprise linguistic variables. The predicate and postdicate of a linguistic rule can be joined into a fuzzy set using logic operators like complements, union, and intersection.

## 2.4 Fuzzy Rule Based Reasoning System (FIS)

According to (Sabri et al., 2013) a FIS's knowledge base is made up of fuzzy sets and fuzzy rule forms. Fuzzification, inference, and defuzzification are the other three components that make up a fuzzy reasoning system in addition to the knowledge base. These three components are shown in Figure 2.6.

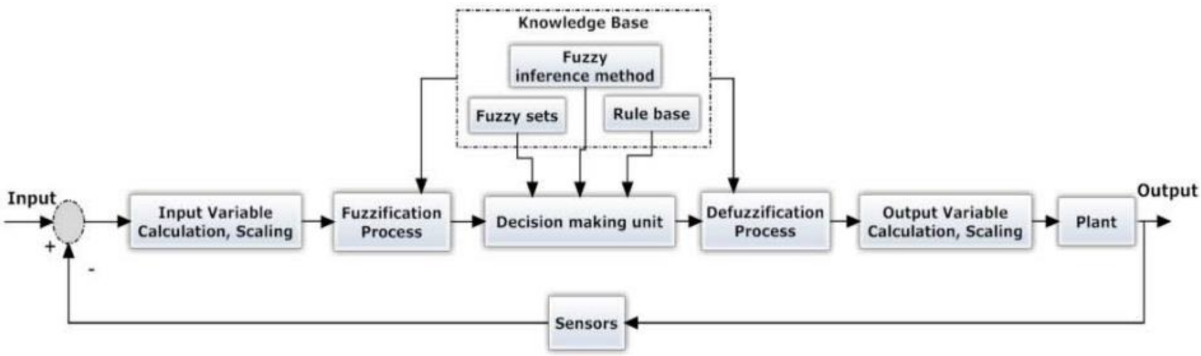



Figure 2.6: Fuzzy inference system (Sabri et al., 2013)

### 2.4.1 Fuzzification

According to (Sabri et al., 2013) A mathematical process called fuzzification transforms a discourse element into a membership value of the fuzzy set.

### 2.4.2 Fuzzy Inference

According to (Sabri et al., 2013) A given input can be mapped to an output utilizing fuzzy logic, membership functions, logical operations, and if-then rules using the inference mechanism. The goal is to produce a fuzzified output for each rule by mapping the fuzzified inputs (as they are received from the fuzzification process) to the rule base.

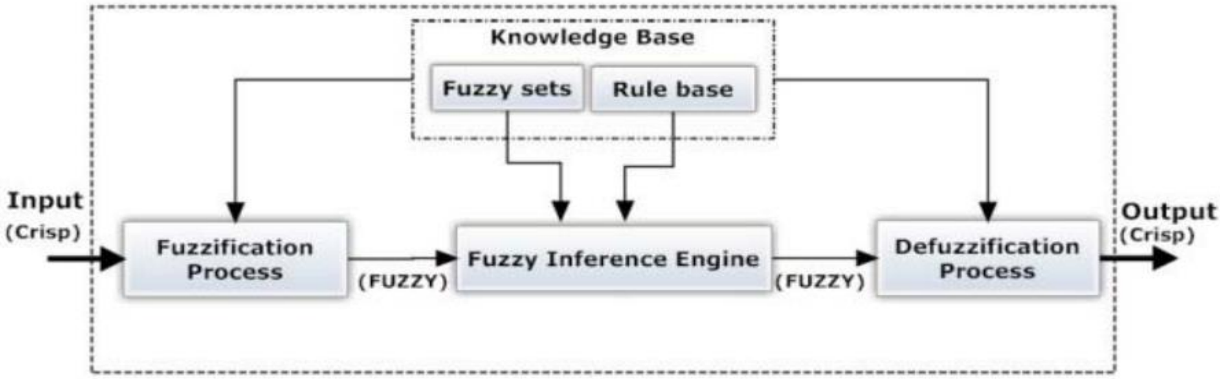



Figure 2.7: Fuzzy Inference Architecture (Sabri et al., 2013)

In other words, the degrees of membership in the input sets and the connections between the input sets are used to calculate the degree of membership to the output sets for the consequents in the rule output space.

The connections between the input sets that are determined by the logic operators combining the sets in the antecedent. The resultant output fuzzy sets are then joined to provide a single overall membership function for the rule's output.

### 2.4.3 Defuzzification

According to (Sabri et al., 2013) A fuzzy set is mathematically transformed into a real number through the process of defuzzification. Fuzzy systems must mathematically merge the fuzzy sets produced by fuzzy inference in order to provide a single number as their output. Defuzzification is calculated for each output variable separately but in a very similar way for fuzzy systems with more than one output variable.

Defuzzifiers come in several forms. Center of Gravity approach modeling and Mamdani inference method are the two widely utilized defuzzification strategies.

## 2.5 Fuzzy ontology

According to (Lee et al., 2005) A development of the domain ontology with crisp ideas is the fuzzy ontology. When attempting to solve problems involving uncertainty reasoning, domain knowledge is more appropriate to use as a description than domain ontology.

### 2.5.1 Differences between Fuzzy Ontology and Classical Ontology

The table in the figure below shows the main differences between fuzzy ontology and crisp ontology:

| **Aspect** | **Fuzzy Ontology** | **Crisp Ontology** |
|---|---|---|
| Multiply-Located terms | Does not occur | Issue for disambiguation |
| Query expansion | Depends on membership value | Depends on location only |
| Customisation | Simple, based on modification of membership values | Review new ontology and/or ontology sharing |
| Intermediate locations for grouping | Unnecessary | Needed for construction – may be useful |
| Storage required | Depends on the number of terms in the ontology and the membership values of the relations, can be smaller or larger than crisp | Depends on the number of terms in the ontology |
| Knowledge representation | Relted to use | Relted to structure |

Table 2.1: Main differences between fuzzy and crisp ontology (Devadoss et al., 2015)

## 2.6 Related works

The table below is a comparative table of multiple related works

| | |
|---|---|
| A Smart IoT platform for personalized healthcare monitoring using semantic technologies | (Dridi et al., 2017) in order to introduce an IoT-based solution for healthcare applications have proposed the SM-IoT platform, an Internet of Things-based platform for smart and personalized healthcare that is committed to both patients and caregivers. This platform's objectives are to advance healthcare services and enhance remote patient monitoring. The SM-IoT platform offers intelligent, individualized e-health services for patients, a |

| | |
|---|---|
| | clever framework that streamlines clinical activities and enhances professional decision-making, and a safe environment for managing personal health data. |
| An Ontological Proposal for the Assistance of People with Disabilities | Identifying the accessibility obstacles that people exhibit, the work of (Rosales-Huamani et al., 2022) contributes to the analysis of several ontological frameworks connected to people with disabilities conducted in recent years. It is suggested to develop a conceptual architecture for people with physical and visual impairments that incorporates a meta-ontology with these features. to condense all the research that has been done. Based on this, the researchers suggest in their study the construction of an architecture that makes use of integration and interoperability qualities to combine the numerous ontological works. |
| A Review of Recent Advances for Preventing, Diagnosis and Treatment of Diabetes Mellitus using Semantic Web | (Göğebakan et al., 2021) examine current ontology-based intelligent systems for diabetes patient prevention, diagnosis, and treatment. We contrast the approaches in terms of their objectives, ontologies, technological advancements, user interfaces, reasoning prowess, assessment metrics, and software. We also offer information on current trends and upcoming directions. |
| To Medical Ontology Fuzzification Purpose: COVID-19 Study Case | (Akremi et al., 2022) present a method to represent erroneous familiarity in a fuzzy structure. The enlarged CFO can be used to investigate a specific medical field (COVID-19). The structural analysis is when the fuzzification process for the CCO ontological structure is introduced. Identifying items that can be fuzzified in the crisp domain is the goal of this point. |
| An ontology-based fuzzy decision support system for multiple sclerosis | (Esposito et al., 2011) built an ontology-based fuzzy decision support system (DSS) has been built to help neuroradiologists automatically classify a particular type of MS lesion. |
| The innovation of the internet: a semantic network analysis of the Internet of Things | (Kim et al., 2017) used word frequency, co-occurrence, and distance analysis to examine how academics perceived the Internet of Things. The semantic network revealed a number of clusters, including cloud computing and big data, smart homes and smart grids, sensor networking, physical networking, environmental monitoring and security, and cloud and physical networking. Future research suggestions are covered. This study offers the empirical data necessary to understand why the acceptance rates for IoT technologies are fluctuating. Explores who is leading or trailing the adoption of this new technology across a range of social areas. |

| | |
|---|---|
| A fuzzy ontology modeling for case base knowledge in diabetes mellitus domain | (El-Sappagh et al., 2017) By publishing a brand-new case-based fuzzy OWL2 ontology (CBRDiabOnto), the study of diabetes diagnostic CBR is advanced. The first fuzzy case-base ontology in the medical field can be regarded as this one. CBRDiabOnto is a brand-new ontology that they created. For any CBR system, the knowledge of DM diagnosis is represented via an OWL-2 fuzzy CB ontology. They focus on the CB fuzzy ontology's knowledge representation formalism. Using this ontology, a complete CBR system has been constructed. The suggested ontology may model a variety of feature kinds, including text, ordinal, semantic, numerical, and fuzzy types. The knowledge base that is produced as a result supports several types of reasoning, including semantic, crisp, and fuzzy reasoning in fuzzy CBR systems. |
| A fuzzy-ontology-oriented case-based reasoning framework forsemantic diabetes diagnosis | (El-Sappagh et al., 2015) describe a fuzzy KI-CBR framework that effectively integrates fuzzy logic into the ontology-based CBR paradigm to handle and exploit imprecise information. To create an intelligent CBR for diabetes diagnosis, fuzzy case-baseontology and a fuzzy semantic retrieval algorithm are proposed and merged. |

Table 2.2: Comparative table of related works

## 2.8 Discussion

In the previous section, several works that discussed and used iot, semantic web and fuzzy logic in the field of healthcare were mentioned. It showed very good results. Because of that, we were inspired to take advantage and apply this technological development for the benefit of the elderly and people with disabilities. Especially with some shortcomings in the aforementioned studies and works. And for this we will present our own model that integrates two disciplines of IoT and semantic web in addition to the approach method of fuzzy logic aiming to facilitate the lives of the elderly and people with disabilities as much as possible.

## 2.8 Conclusion

In this chapter, we have presented the disciplines of IoT and semantic web also fuzzy logic. This technologies and approach method could be a reason to make a difference in the lives of the elderly and people of disabilities. In the next chapter we will present our approach that we believe can make improvements comparison previous works and studies and we will discuss it in detail.

# Chapter 3

# Conception

## 3.1 Introduction

In this chapter we will discuss in details how we will use fuzzy logic for enhancing decisions that will benefit people with disabilities and the elderly in their daily lives by eliminating barriers they face as much as possible.

## 3.2 Objective of the proposed method

Our goal is to remove barriers facing the elderly and people with disabilities, and by exploiting the development of technology we will collect data from them. After that, we will take advantage of semantic web for a clearer understanding of this data, and we will use fuzzy logic to enhance the decisions that they were made by semantic web. We will discuss our proposed method in the next section of this chapter.

## 3.3 Architecture of the proposed system

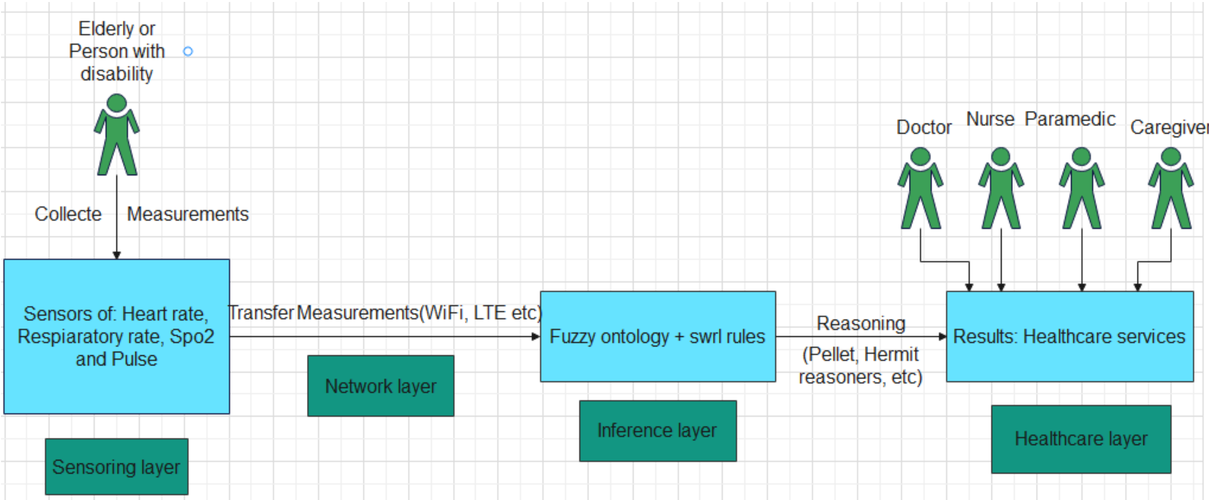



Figure 3.1: Architecture of the proposed system

**Explanation:** First in the sensoring layer, the sensors stars collecting measurements of vital signs from the elderly and people with disabilities and transfer it via Wi-Fi, LTE ,etc which represents the network layer to our inference layer . After that we use swrl rules and fuzzy ontology for reasoning to infer new knowledge and make perfect healthcare service recommendations to the patients.

## 3.4 The ontology

We created an ontology to describe the environment and the healthcare field related to the elderly and people with disabilities. In the following section we will make presentation of knowledge of this environment.

### 3.4.1 Classes

1. **Person**
    - Person_with_disability
    - Elderly
    - Doctor
    - Nurse
    - Caregiver
    - Paramedic
2. **Type_of_disability**
    - Sensory
    - Mental
    - Physical
3. **Vital_sign**
    - Heart_rate
    - Respiratory_rate
    - Spo2
    - Pulse
4. **Sensor**
    - Heart_rate_sensor
    - Respiratory_rate_sensor
    - Spo2_sensor
    - Puse_sensor
    - Camera
    - GPS
5. **Healthcare service**
    - Hospitalization
    - Medication
    - Medical_advice

6. **Adaptive_device**

- White_cane
- Blind_stick
- Prosthetic
- Anti_bedsore_mattress

7. **Medical_History**

- Asthma
- Diabetes
- Alzheimer
- Hypertension
- Cancer
- Influenza

8. **Activity**

- Shopping
- Course
- Study
- Travel
- Walk
- Work

9. **Obstacle**

- Curb
- Pit
- Stairs
- Unfavorable_weather

10. **Symptom**

- Change_in_apetite
- Change_in_weight
- Cough
- Dizziness

- Vomiting
- Dry_mouth
- Fainting
- Fatigue
- Fever
- Dyspnea
- Nausea
- Tightness_in_chest
- Headache
- Wheezing

11. **Location**

| **Classe** | **Description** |
|---|---|
| Person | A human. It regroups Elderly, person with disability, Doctor, Nurse, Caregiver and Paramedic. |
| Person_with_disability | A person who has disability. |
| Elderly | A person who is 65 or older |
| Doctor | A person who can treats elderly or Person with disability. |
| Nurse | A person who can assists an elderly or Person with disability depending on their needs or doctor instructions. |
| Caregiver | A person who give care services for elderly and Person with disability. it can be family member, friends or hired person. |
| Paramedic | A person who give emergency medical care to an elderly or person with disability. |
| Type_of_disability | Categories of impairments Person with disability can have containg 3 subclasses which are: Sensory, Mental and Physical. |
| Vital_sign | A numeric value gathered from sensors containg 4 subclasses which are: Heart rate, Respiratory rate, Spo2 or Pulse . |
| Sensor | A device that is connected to an elderly or Person with disability patient and the semantic system, It gathers measurements and transfer it to the system containg 4 subclasses which are: Heart rate sensor, Respiratory rate sensor, Spo2 sensor or Pulse sensor. |

| | |
|---|---|
| Healthcare_service | Some treatments for the elderly or Person with disability containg 3 subclasses which are: Hospitalization, Medication and Medical advice . |
| Adaptive_device | Devices that can assist Person with disability or elderly containg 4 subclasses which are: White_cane, Wheelchair, Prosthetic, Anti_bedsore_mattress. |
| Disease | Diseases that Person with disability or elderly can have, containg 6 subclasses which are: Asthma, Diabetes, Alzheimer, Hypertension, Cancer, Influenza. |
| Activity | Something that Person with disability or elderly wants to do containg 6 subclasses which are: Shopping, Travel, Study, Work, Walk, Course. |
| Obstacle | Something that interrupt Person with disability or elderly while he is doing or wants to do an activity, containg 4 subclasses which are: Curb, Pit, Stairs and Unfavourable weather. |
| Symptom | A sign regarded as indicating disease, containg 14 subclasses which are: Change in apetite, Change in weight, Dizziness, Fainting, Vomiting, Dry mouth, Cough, Fever, Fatigue, Headache, Tightness in chest, Dyspnea, Nausea and Wheezing. |
| Location | A place defined by coordinates in the map. |

Table 3.1: List of classes

## 3.4.2 Object properties

In ontology , The object properties represents the relationships between objects. the next table contains all relations between objects in our ontology:

| **Object Property** | **Domain** | **Range** | **Description** |
|---|---|---|---|
| Requires_hospitalization | Person_with_disability<br>Elderly | Hospitalization | Relation connects the person with disability or elderly with service Hospitalization. |
| Requires_medication | Person_with_disability<br>Elderly | Medication | Relation connects the person with disability or elderly with service Medication. |

| | | | |
|---|---|---|---|
| Requires_medical_advice | Person_with_disability Elderly | Medical_advice | Relation connects the Person_with_disability or Elderly with service Medicaal_advice. |
| Has_hr | HR_sensor | Heart_rate | Relation connects the HR_sensor with Heart_rate. |
| Has_rr | RR_sensor | Respiratory_rate | Relation connects the RR_sensor with Respiratory_rate. |
| Has_spo2 | Spo2_sensor | Spo2 | Relation connects the Spo2_sensor with Spo2. |
| Has_pulse | Pulse_sensor | Pulse | Relation connects the Pulse_sensor with Pulse. |
| Has_hr_sensor | Person_with_disability Elderly | HR_sensor | Relation connects the Person_with_disability or Elderly with HR_sensor. |
| Has_rr_sensor | Person_with_disability Elderly | RR_sensor | Relation connects the Person_with_disability or Elderly with RR_sensor. |
| Has_spo2_sensor | Person_with_disability Elderly | Spo2_sensor | Relation connects the Person_with_disability or Elderly with Spo2_sensor. |
| Has_pulse_sensor | Person_with_disability Elderly | Pulse_sensor | Relation connects the Person_with_disability or Elderly with Pulse_sensor. |

| | | | |
|---|---|---|---|
| Is_assisted_by | Person_with_disability Elderly | Nurse | Relation that connects Person with disability or Elderly with Nurse describe the action assisted by |
| Is_cared_by | Person_with_disability Elderly | Caregiver | Relation that connects Person with disability or Elderly with Caregiver describe the action cared by |
| Is_treated_by | Person_with_disability Elderly | Doctor | Relation that connects Person with disability or Elderly with Caregiver describe the action treated by |
| Is_helped_by | Person_with_disability Elderly | Paramedic | Relation that connects Person with disability or Elderly with Paramedic describe the action helped by |
| Helps | Paramedic | Person_with_disability<br><br>Elderly | Relation that connects Paramedic with Person disability or Elderly describe the action helps |
| Treats | Doctor | Person_with_disability<br><br>Elderly | Relation that connects Doctor with Person with disability or Elderly describe the action treats |
| Cares_for | Craegiver | Person_with_disability<br><br>Elderly | Relation that connects Caregiver with Person with disability or Elderly describe the action Craes_for |

| | | | |
|---|---|---|---|
| Assists | Nurse | Person_with_disability<br>Elderly | Relation that connects Nurse with Person with disability or Elderly describe the action assists |
| Detects_location | GPS | Location | Relation that connects GPS with location describe the action detects location |
| Detects_obstacle | White_cane<br>Camera | Obstacle | Relation that connects Whie cane and camera with obstacle describe the action detects obstacle |
| Has_activity | Person_with_disability<br>Elderly | Activity | Relation that connects person with disability or elderly with activity |
| Has_adaptive_device | Person_with_disability<br>Elderly | Adaptive_device | Relation that connects person with disability or elderly with adaptive device |
| Has_camera | Person_with_disability<br>Elderly | Camera | Relation that connects person with disability or elderly with camera |
| Has_disease | Person_with_disability<br>Elderly | Disease | Relation that connects person with disability or elderly with disease |
| Has_gps | Person_with_disability<br>Elderly | GPS | Relation that connects person with disability or elderly with GPS |
| Has_location | Person_with_disability<br>Elderly | Location | Relation that connects person with disability or elderly with Location |
| Has_obstacle | Person_with_disability<br>Elderly | Obstacle | Relation that connects person with disability or elderly with Obstacle |
| Has_symptom | Person_with_disability<br>Elderly | Symptom | Relation that connects person with disability or elderly with Symptom |
| Has_type_of_disability | Person_with_disability<br>Elderly | Type_of_disability | Relation that connects person with disability or elderly with Type of disability |

Table 3.2: List of Object properties

### 3.4.3 Data properties

| Data Propriety | Domain | Range | Description |
|---|---|---|---|
| Age | Person | Integer | The age of person |
| First_name | Person | String | The given name to a person. |
| Last_name | Person | String | The family name of a person. |
| Sex | Person | String | The sex of the person. |
| Time | Vital_sign | String | Time of vital_sign measuerment. |
| Value | Vital_sign | Integer | A number that describe a Vital sign. |

Table 3.3: List of data proprieties

## 3.5 Swrl rules

We enriched our system with a set of 29 rules chosen by Dr. Benabbase Mourad a general practitioner; we will explain each one of them in the next lines:

**Rule 1:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate<12, spo2<94, heart rate<44 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , lessThan(?vr, 12) , lessThan(?vs, 94) , lessThan(?vh, 44) , Hospitalization(?hcs) -> Requires_hospitalization(?p, ?hcs)*

**Rule 2:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 11<respiratory rate<21, spo2<94, heart rate<44 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr, 11) , lessThan(?vr, 21) , lessThan(?vs, 94) , lessThan(?vh, 44) , Hospitalization(?hcs) -> Requires_hospitalization(?p, ?hcs)*

**Rule 3:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <20, spo2<94, heart rate<44 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr, 20) , lessThan(?vs, 94) , lessThan(?vh, 44) , Hospitalization(?hcs) -> Requires_hospitalization(?p,?hcs)*

**Rule 4:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2>93, heart rate<44 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , lessThan(?vr,12) , greaterThan(?vs,93) , lessThan(?vh, 44) , Hospitalization(?hcs) -> Requires_hospitalization(?p,?hcs)*

**Rule 5:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 11<respiratory rate <21, spo2>93, heart rate<44 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,11) , lessThan(?vr,21) , greaterThan(?vs,93) , lessThan(?vh, 44) , Hospitalization(?hcs) -> Requires_hospitalization(?p,?hcs)*

**Rule 6:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate>20, spo2<93, heart rate<44 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,20) , greaterThan(?vs,93) , lessThan(?vh, 44) , Hospitalization(?hcs) -> Requires_hospitalization(?p,?hcs)*

**Rule 7:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2<94, 43<heart rate<60 then this person requires Medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , lessThan(?vr,12) , lessThan(?vs,94) , greaterThan(?vh,43) , lessThan(?vh,60) , Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 8:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 11<respiratory rate <22, spo2<94, 43< heart rate<60 then this person requires Medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,11),lessThan(?vr,22) , lessThan(?vs,94) , greaterThan(?vh,43) , lessThan(?vh,60) , Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 9:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2>93, 43<heart rate<60 then this person requires Medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,20),lessThan(?vs,94),greaterThan(?vh,43),lessThan(?vh,60),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 10:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 12<respiratory rate , spo2>93, 43<heart rate<60 then this person requires Medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , lessThan(?vr,12),greaterThan(?vs,93),greaterThan(?vh,43),lessThan(?vh,60),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 11:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 11<respiratory rate <22, spo2>93, 43<heart rate<60 then this person requires Medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,11),lessThan(?vr,22),greaterThan(?vs,93),greaterThan(?vh,43),lessThan(?vh,60),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 12:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate >20, spo2>93, 43<heart rate<60 then this person requires Medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,20),greaterThan(?vs,93),greaterThan(?vh,43),lessThan(?vh,60),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 13:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2<94, 59<heart rate<101 then this person requires medical_advice.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , lessThan(?vr,12),lessThan(?vs,94),lessThan(?vh,101),greaterThan(?vh,59),Medical_advice(?hcs) -> Requires_medical_advice(?p,?hcs)*

**Rule 14:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 11<respiratory rate <21, spo2<94, 59< heart rate<101 then this person requires medical_advice.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,11),lessThan(?vr,21),lessThan(?vs,94),lessThan(?vh,101),greaterThan(?vh,59),Medical_advice(?hcs) -> Requires_medical_advice(?p,?hcs)*

**Rule 15:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate >20, spo2<94, 59<heart rate<101 then this person requires medical_advice.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,20),lessThan(?vs,94),lessThan(?vh,101),greaterThan(?vh,59),Medical_advice(?hcs) -> Requires_medical_advice(?p,?hcs)*

**Rule 16:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2>93, 59<heart rate<101 then this person requires medical_advice.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) ,* *lessThan(?vr,12),greaterThan(?vs,93),lessThan(?vh,101),greaterThan(?vh,59),Medical_advice(?hcs) -> Requires_medical_advice(?p,?hcs)*

**Rule 17:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate >20, spo2>93, <59heart rate<101 then this person requires medical_advice.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,20),greaterThan(?vs,93),lessThan(?vh,101),greaterThan(?vh,59),Medical_advice(?hcs) -> Requires_medical_advice(?p,?hcs)*

**Rule 18:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2<94, 100<heart rate<116 then this person requires medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , lessThan(?vr,12),lessThan(?vs,94),greaterThan(?vh,100),lessThan(?vh,116),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 19:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <21, spo2<94, 100<heart rate<116 then this person requires medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,11), lessThan(?vr,21),lessThan(?vs,94),greaterThan(?vh,100),lessThan(?vh,116),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 20:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 20<respiratory rate, spo2<94, 100<heart rate<116 then this person requires medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) ,* *greaterThan(?vr,20),lessThan(?vs,94),greaterThan(?vh,100),lessThan(?vh,116),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 21:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2>93, 100<heart rate<116 then this person requires medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , lessThan(?vr,12),greaterThan(?vs,93),greaterThan(?vh,100),lessThan(?vh,116),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 22:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <21, spo2>93, 100<heart rate<116 then this person requires medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,11), lessThan(?vr,21),greaterThan(?vs,93),greaterThan(?vh,100),lessThan(?vh,116),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 23:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate >20, spo2>93, 100<heart rate<116 then this person requires medication.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,20),greaterThan(?vs,93),greaterThan(?vh,100),lessThan(?vh,116),Medication(?hcs) -> Requires_medication(?p,?hcs)*

**Rule 24:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2<94, heart rate>115 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms,*

*?vs) , Value(?mh, ?vh) , lessThan(?vr, 12) , lessThan(?vs, 94) , greaterThan(?vh, 115) , Hospitalization(?hcs) -> Requires_hospitalization(?p, ?hcs)*

**Rule 25:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 11<respiratory rate <21, spo2<94, heart rate<115 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr, 11) , lessThan(?vr, 21) , lessThan(?vs, 94) , greaterThan(?vh, 115) , Hospitalization(?hcs) -> Requires_hospitalization(?p, ?hcs)*

**Rule 26:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate >20, spo2<94, heart rate>115 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr, 20) , lessThan(?vs, 94) , greaterThan(?vh, 115) , Hospitalization(?hcs) -> Requires_hospitalization(?p,?hcs)*

**Rule 27:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate <12, spo2>93, heart rate<115 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , lessThan(?vr,12) , greaterThan(?vs,93) , greaterThan(?vh, 115) , Hospitalization(?hcs) -> Requires_hospitalization(?p,?hcs)*

**Rule 28:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: 11<respiratory rate<21, spo2<94, heart rate<115 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,11) , lessThan(?vr,21) , greaterThan(?vs,93) , greaterThan(?vh, 115) , Hospitalization(?hcs) -> Requires_hospitalization(?p,?hcs)*

**Rule 29:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate >20, spo2>93, heart rate<115 then this person requires hospitalization.

*Person_with_disability(?p) , RR_sensor(?sr) , Spo2_sensor(?ss) , HR_sensor(?sh) , Has_rr_sensor(?p,?sr) , Has_spo2_sensor(?p, ?ss) , Has_hr_sensor(?p, ?sh) , Has_rr(?sr,?mr) , Has_spo2(?ss,?ms) , Has_hr(?sh,?mh) , Value(?mr, ?vr) , Value(?ms, ?vs) , Value(?mh, ?vh) , greaterThan(?vr,20) , greaterThan(?vs,93) , greaterThan(?vh, 115) , Hospitalization(?hcs) -> Requires_hospitalization(?p,?hcs)*

# 3.6 Fuzzy logic

Now we will explain the fuzzy part of our system:

## 3.6.1 Fuzzy ontology

The first step is to make a fuzzy ontology which is an extension of the classical one that we did. That allows us to add datatypes (in fuzzy ontology also known as: fuzzy datatypes) so we can represent ranges of the vital signs which is the factor that our healthcare service recommendations based on, and it is a general guidelines for adults between 18 and 50 because the lack of data sets.

We choose type of membership function to represent our ranges which “Trapezoidal” and parameters of it. We choose trapezoidal because it is distinguished of Better accuracy ( because it can represent a wider range of values), More flexibility and Easier to interpret.

Our new datatypes with value and data range expression (that They were given by a doctor) are shown in the table below:

**Note 1**: “A”, “B”, “C” and “D” are parameters that define the shape of the membership function.
**A:** The lower-left point and bound of the set indicating the beginning of the trapezoidal.
**B:** The upper-left point indicating the rising edge of the trapezoidal.
**C:** The upper-right point indicating the falling edge of the trapezoidal.
**D:** The lower-right point and the upper bound of the set indicating the end of the trapezoidal.

**Note 2**: measuring units of our vital sign are :
Heart rate, Pulse : Beats per minute (bpm)
Spo2: %
Respiratory rate: Breaths per minute (bpm)

| **Datatype name** | **Data range expression** | **Value** |
|---|---|---|
| TooLowHeartRate | (double[>= 0.0] and double[<= 48.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="0" b="0" c="40" d="48" /><br></fuzzyOwl2> |
| LowHeartRate | (double[>= 40.0] and double[<=64.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="40" b="48" c="56" d="64" /><br></fuzzyOwl2> |
| NormalHeartRate | double[>= 56.0] and double[<= 104.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="56" b="64" c="96" d="104" /><br></fuzzyOwl2> |
| HighHeartRate | (double[>= 96.0] and double[<=120.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="96" b="104" c="112" d="120" /><br></fuzzyOwl2> |
| TooHighHeartRate | (double[>= 112.0] and double[<=220.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="112" b="120" c="220" d="220" /><br></fuzzyOwl2> |
| LowRespiratoryRate | (double[>= 0.0] and double[<= 14.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="0" b="0" c="10" d="14" /><br></fuzzyOwl2> |

| | | |
|---|---|---|
| NormalRespiratoryRate | (double[>= 10.0] and double[<=22.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="10" b="14" c="18" d="22" /><br></fuzzyOwl2> |
| HighRespiratoryRate | (double[>= 18.0] and double[<=44.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="18" b="22" c="44" d="44" /><br></fuzzyOwl2> |
| LowSpo2 | (double[>= 0.0] and double[<=96.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="0" b="0" c="92" d="96" /><br></fuzzyOwl2> |
| NormalSpo2 | (double[>= 92.0] and double[<=100.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="92" b="96" c="100" d="100"/><br></fuzzyOwl2> |
| TooLowPulse | (double[>= 0.0] and double[<= 48.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="0" b="0" c="40" d="48" /><br></fuzzyOwl2> |
| LowPulse | (double[>= 40.0] and double[<=64.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="40" b="48" c="56" d="64" /><br></fuzzyOwl2> |

| | | |
|---|---|---|
| NormalPulse | double[>= 56.0] and double[<= 104.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="56" b="64" c="96" d="104" /><br></fuzzyOwl2> |
| HighPulse | (double[>= 96.0] and double[<=120.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="96" b="104" c="112" d="120" /><br></fuzzyOwl2> |
| TooHighPulse | (double[>= 112.0] and double[<=220.0]) | <fuzzyOwl2 fuzzyType="datatype"><br><Datatype type="trapezoidal" a="112" b="120" c="220" d="220" /><br></fuzzyOwl2> |

Table 3.4: List of fuzzy datatypes

### 3.6.2 Fuzzy swrl

Now, we will talk about the fuzzy swrl rules, which they are extension of swrl rules and based on fuzzy logic chosen by Dr. Benabbase Mourad a general practitioner. We will explain each one of them and how they are helping to make better decision for the elderly and people with disabilities:

**Rule 1:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Low, heart rate: TooLow then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooLowHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 2:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Low, heart rate: TooLow then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooLowHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 3:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Low, heart rate: TooLow then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooLowHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 4:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Normal, heart rate: TooLow then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooLowHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 5:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Normal, heart rate: TooLow then this person requires *hospitalization*.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooLowHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 6:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Normal, heart rate: TooLow then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooLowHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 7:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Low, heart rate: Low then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^LowHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 8:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Low, heart rate: Low then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^LowHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 9:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Low, heart rate: Low then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^LowHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 10:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Normal, heart rate: Low then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^LowHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 11:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Normal, heart rate: Low then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^LowHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 12:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Normal, heart rate: Low then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh)*

*^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^LowHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 13** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Low, heart rate: Normal then this person requires medical advice.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^NormalHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Medical_advice(?hcs) ^ Requires_medical_advice(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medical_advice(?p, ?hcs)*

**Rule 14:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Low, heart rate: Normal then this person requires medical_advice.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^NormalHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Medical_advice(?hcs) ^ Requires_medical_advice(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medical_advice(?p, ?hcs)*

**Rule 15:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Low, heart rate: Normal then this person requires medical_advice.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^NormalHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medical_advice(?hcs) ^ Requires_medical_advice(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medical_advice(?p, ?hcs)*

**Rule 16:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Normal, heart rate: Normal then this person requires medical_advice.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^NormalHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medical_advice(?hcs) ^ Requires_medical_advice(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medical_advice(?p, ?hcs)*

**Rule 17:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Normal, heart rate: Normal then this person requires medical_advice.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^NormalHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medical_advice(?hcs) ^ Requires_medical_advice(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medical_advice(?p, ?hcs)*

**Rule 18:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Low, heart rate: High then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^HighHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 19:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Low, heart rate: High then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^HighHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 20:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Low, heart rate: High then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^HighHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 21:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Normal, heart rate: High then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^HighHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 22:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Normal, heart rate: High then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^HighHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 23:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Normal, heart rate: High then this person requires medication.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^HighHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Medication(?hcs) ^ Requires_medication(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_medication(?p, ?hcs)*

**Rule 24:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Low, heart rate: TooHigh then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooHighHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 25:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Low, heart rate: TooHigh then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooHighHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 26:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Low, heart rate: TooHigh then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooHighHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ LowSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 27:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Low, spo2: Normal, heart rate: TooHigh then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooHighHeartRate(?vh) ^ LowRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 28:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: Normal, spo2: Normal, heart rate: TooHigh then this person requires hospitalization.

*Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooHighHeartRate(?vh) ^ NormalRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d) ^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)*

**Rule 29:** If a person with disability connects to three sensors of: respiratory rate, Spo2 and heart rate. And this sensors have the following measurements of the vital signs: respiratory rate: High, spo2: Normal, heart rate: TooHigh then this person requires hospitalization.

Person_with_disability(?p) ^ RR_sensor(?sr) ^ Spo2_sensor(?ss) ^ HR_sensor(?sh) ^Has_rr_sensor(?p, ?sr) ^ Has_spo2_sensor(?p, ?ss) ^ Has_hr_sensor(?p, ?sh) ^Has_rr(?sr, ?mr) ^ Has_spo2(?ss, ?ms) ^ Has_hr(?sh, ?mh) ^Value(?mr, ?vr) ^ Value(?ms, ?vs) ^ Value(?mh, ?vh) ^TooHighHeartRate(?vh) ^ HighRespiratoryRate(?vr) ^ NormalSPO2(?vs) ^Hospitalization(?hcs) ^ Requires_hospitalization(?p, ?hcs) ^ DegreeOfMembership(?hcs, ?d)

^GreaterThanOrEqual(?d, 0.5) ->Requires_hospitalization(?p, ?hcs)

## 3.7 Application example

We will explain our proposed method with application example as follows:

Lets suppose that there is Person with disability or Elderly called Carl. Carl connects to multiple sensors: heart rate, pulse, spo2 and respiratory rate as the same time his medical profile always updated. This sensors collects measuerments of his vital signs and transfer it via network to the middlware mangment layer. Where this measuerments subject to the process swrl rules and by using inference engine it gives Healthcare service recommendation to the patient. And as the same time this measuerments subject to the process of fuzzy rule based raisoning system (FIS) and also gives healthcare service recommendations. And after obtaining the results and compared of each method we will see that there is difference in some cases where the patient get recommendation more accurate. This helps the medical section enhancing decisions for the elderly and people with disabilities.

## 3.8 Conclusion

At the end of this chapter, we have presented the architecture of our orposed method with explanation, we have also presented classes, objects and data properties. Also, the swrl rules of our system. After thet in the fuzzy part, we explained how to define the membership functions and the the fuzzy swrl rules. Now, in the next chapter we will present the implementation and results of the system.

# Chapter 4

# Implementation

## 4.1 Introduction

After explaining in the previous chapter the conception of our proposed system. Now, we will present the development of the system and we will discuss the main parts of the code and results.

## 4.2 Development of the system

### 4.2.1 Creation of the ontology

The first thing to do is to create the ontology. We will show each part of our ontology that we used protege to craeate:

**Class hierarchy:**

The next two figures shows the classes we created in our ontology, the first one also shows which classes have relationships with eachother:

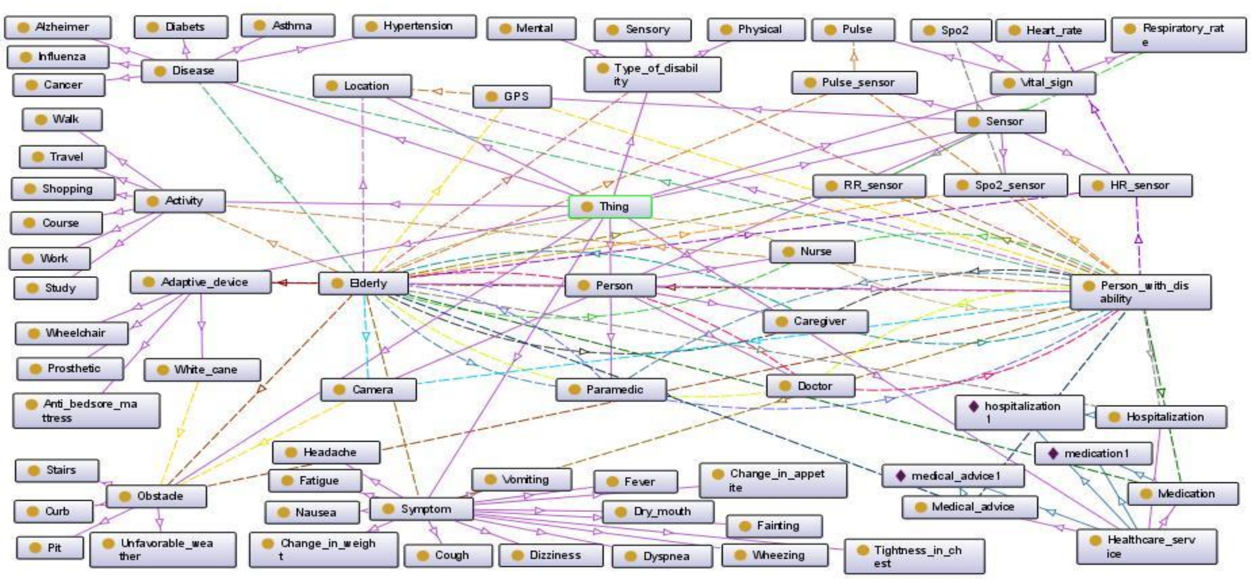



Figure 4.1: Class hierarchy with OntoGraph

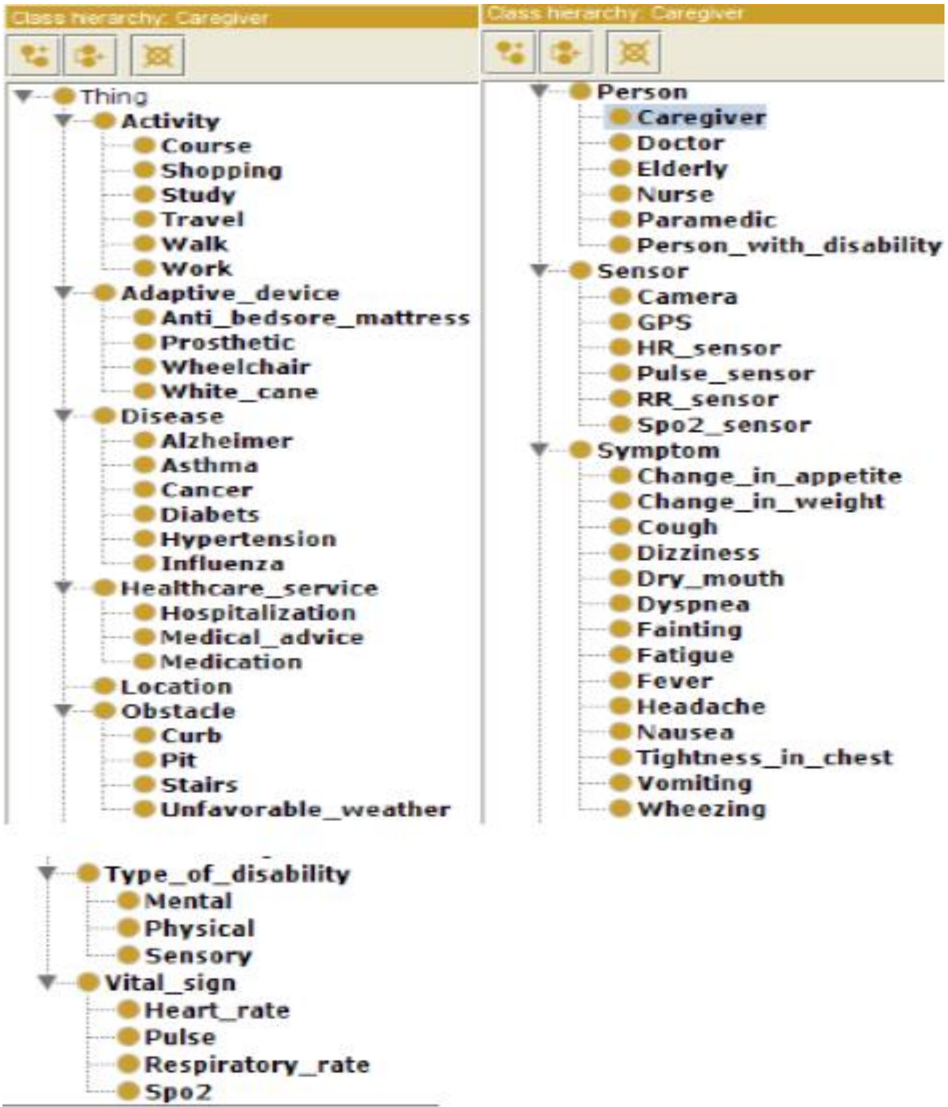



Figure 4.2: Class hierarchy

## Object properties hierarchy:

The next figure shows the object properties we created:

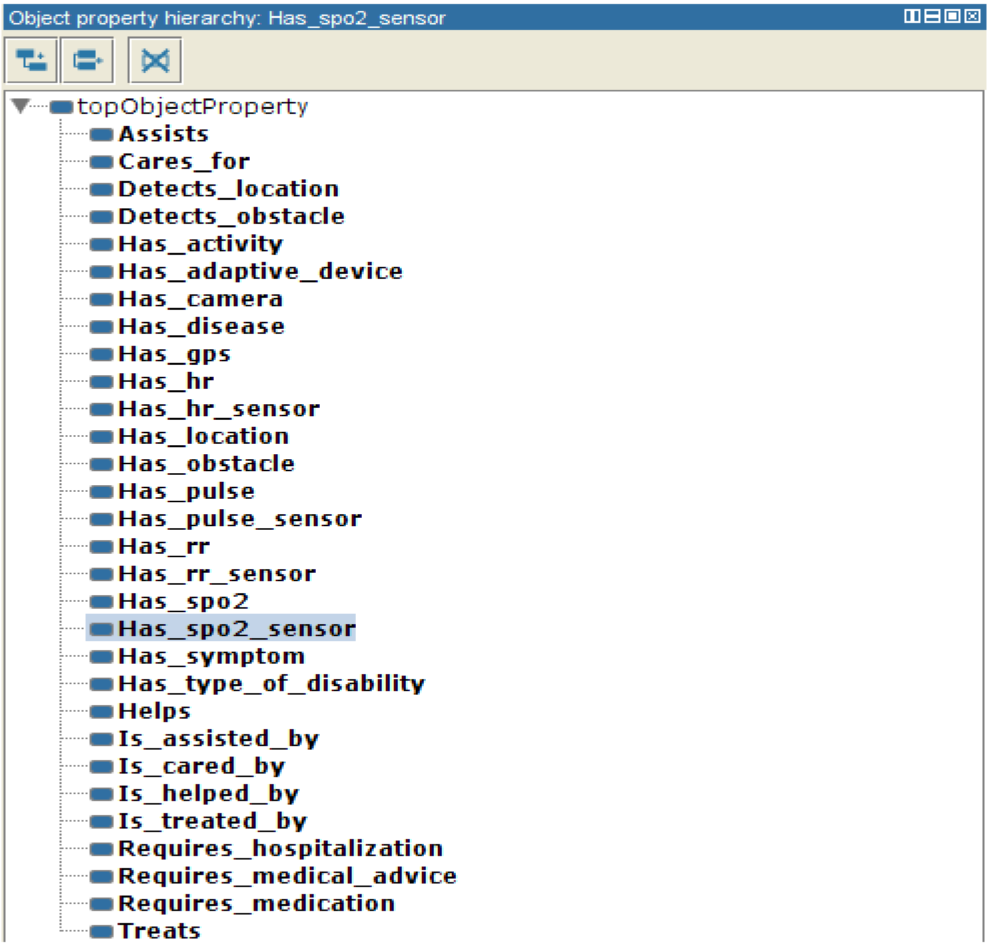



Figure 4.3: Object Property hierarchy

## Data property hierarchy

The next figure shows the data property we created:

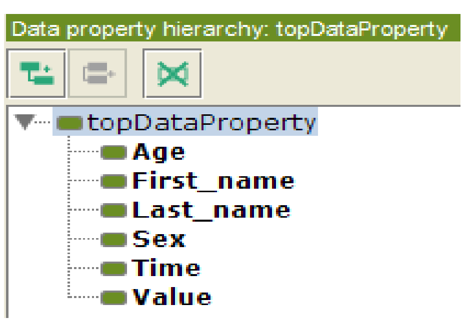



Figure 4.4: Data Propriety hierarchy

**Fuzzy Datatypes:**

This figure shows the adding of fuzzy datatypes using the plug-in “Fuzzy OWL”:

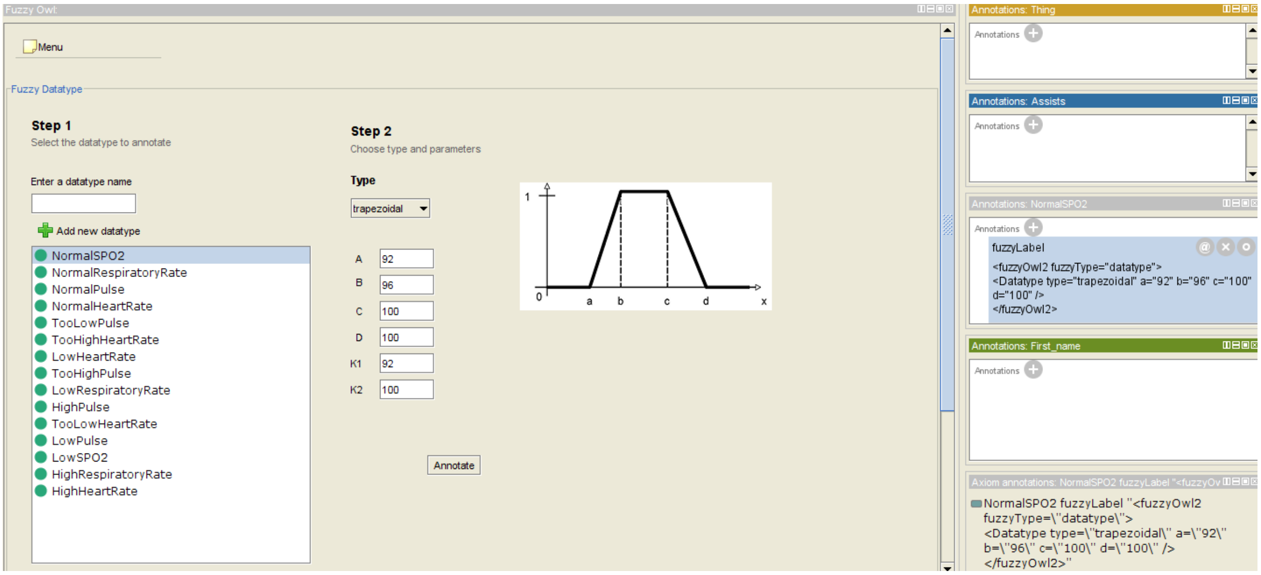



Figure 4.5: The adding of Fuzzy datatypes

## 4.2.2 System over view

### 4.2.2.1 Data set

We have used dataset called BIDMC. We can find it here:

[https://physionet.org/content/bidmc/1.0.0/].

Now we will present the main functions of our system:

### 4.2.2.2 Importing libraries

Now we import libraries that we will going to use in the first part of our code:

```
C: > Users > AdminPC > rdf23.py > ...
# LIBRARIES

import names, csv, random
import owlready2 as owl
import math

print("The Libraries are imported.\n")
```

Figure 4.6: importing libraries

## 4.2.2.3 Loading ontology

The next thing is we load the ontology:

```

# Load Ontology

onto = owl.get_ontology("C:\\Users\\AdminPC\\Health.owl").load()
print("The ontology is loaded.")

```

Figure 4.7: Ontology loading

## 4.2.2.4 Reading data

The next figure shows how to read data:

```
    filename = "bidmc_csv/bidmc_" + n + "_Numerics.csv"
    with open(filename, 'r') as csvfile:
        so = csv.reader(csvfile, delimiter=',', quotechar='"')
        so_data = list(so)
        del so_data[0]
```

Figure 4.8: Reading data

## 4.2.2.5 Adding individual to ontology

The next figure shows how to add individual to ontology:

```
        # GENERATE NAME FROM GENDER
        name = names.get_full_name(gender=g)
        fname_pat = name.split()[0]
        name_pat = name.split()[1]
        # Creating Handicap instance
        person = onto.Person_with_disability()
        person.Last_name = [name_pat]
        person.First_name = [fname_pat]
        person.Age = [int(age)]
        person.Sex = [g]
```

Figure 4.9: Adding individual to ontology

And this figure shows the relationships of the person with disability:

```python
# ADD RELATIONSHIPS
owl.AllDifferent([person, doctor, nurse, caregiver, paramedic])
person.Is_assisted_by = [nurse]
person.Is_treated_by = [doctor]
person.Is_helped_by = [paramedic]
person.Is_cared_by = [caregiver]
```

Figure 4.10: Relationships of the person with disability

And finally we save our ontology:

```python
onto.save(file="Health2.owl", format="rdfxml")
```

Figure 4.11: Saving the ontology

#### 4.2.2.6 Generating RDF files for Person with disability

The next fgure shows a part of the structure of generated RDF file:

```xml
C: > Users > AdminPC > instances_test > Bradley_Johnson.rdf
<?xml version="1.0"?>
 <rdf:RDF
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:PFE="http://www.semanticweb.org/adminpc/ontologies/2023/5/untitled-ontology-76#" >
<rdf:Description rdf:about="http://www.semanticweb.org/adminpc/ontologies/2023/5/untitled-ontology-76#Bradley_Johnson">
<rdf:type rdf:resource="http://www.semanticweb.org/adminpc/ontologies/2023/5/untitled-ontology-76#Person_with_disability"/>
<PFE:Age rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">43</PFE:Age>
<PFE:First_name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Joseph</PFE:First_name>
<PFE:Last_name rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Greenwald</PFE:Last_name>
<PFE:Sex rdf:datatype="http://www.w3.org/2001/XMLSchema#string">male</PFE:Sex>
<PFE:Has_type_of_disability>
<rdf:Description rdf:about="http://www.semanticweb.org/adminpc/ontologies/2023/5/untitled-ontology-76#Mental">
</rdf:Description>
</PFE:Has_type_of_disability>
<PFE:Has_activity>
<rdf:Description rdf:about="http://www.semanticweb.org/adminpc/ontologies/2023/5/untitled-ontology-76#Walk">
</rdf:Description>
</PFE:Has_activity>
<PFE:Has_obstacle>
<rdf:Description rdf:about="http://www.semanticweb.org/adminpc/ontologies/2023/5/untitled-ontology-76#Stairs">
</rdf:Description>
</PFE:Has_obstacle>
<PFE:Has_adaptive_device>
<rdf:Description rdf:about="http://www.semanticweb.org/adminpc/ontologies/2023/5/untitled-ontology-76#Wheelchair">
</rdf:Description>
```

Figure 4.12: Generated RDF file Example

## 4.3 Results

The  three figures below shows the membership functions of  the vital signs :

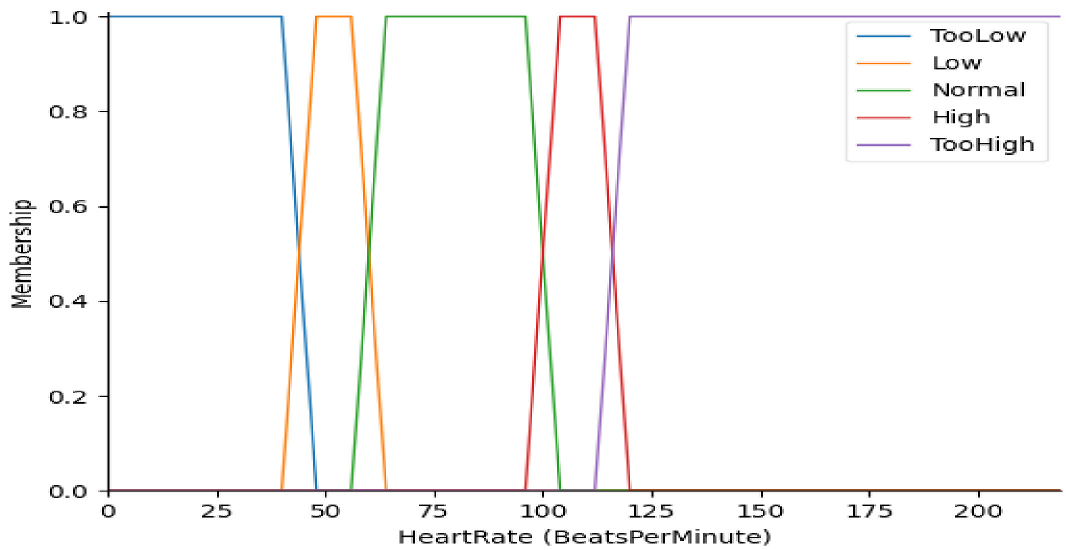



Figure 4.13: Membership function of Heart rate

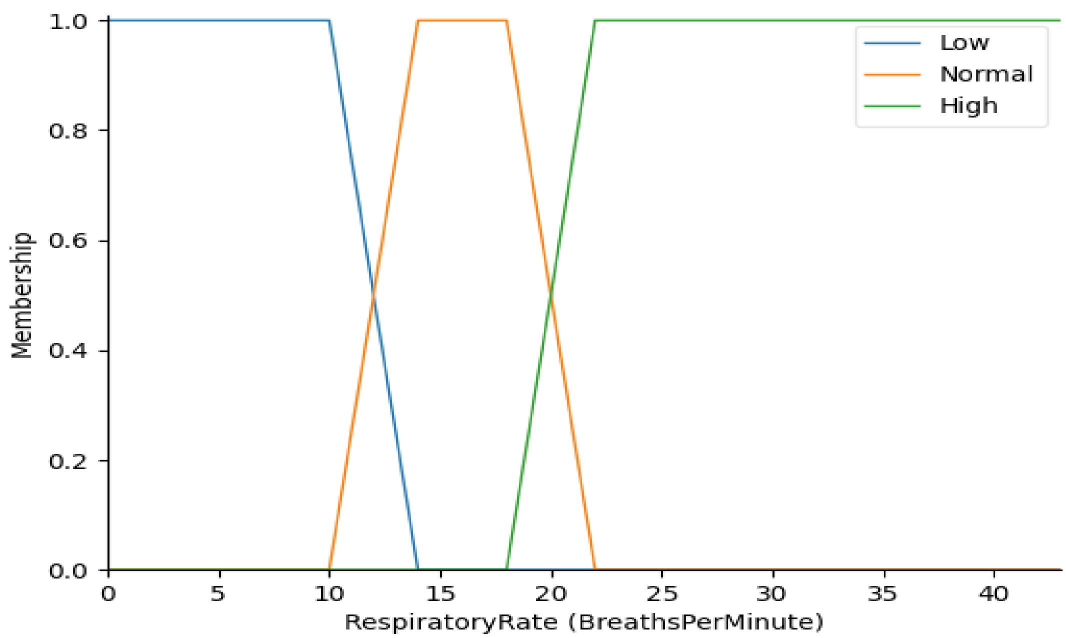



Figure 4.14: Membership function of Respiratory rate

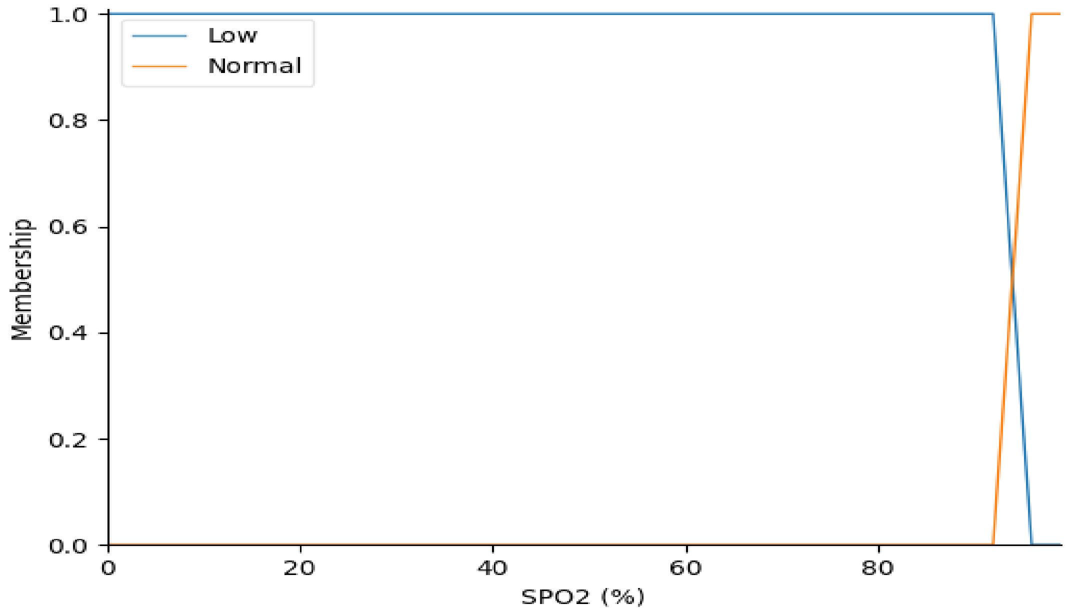



Figure 4.15: Membership function of SPO2

And after excuting the fuzzy part of the code we notice that the output are more precise and given with the likehood of the healthcare service to be given.

# General conclusion

To assist the elderly and people with disabilities, we have used semantic web so there will be no problem of interoperability after collecting data from heterogeneous sources, and we did use Fuzzy logic to handle the problem of uncertainty and vagueness of data. We started by creating a well defined ontology containing classes, object and data properties. We added after that fuzzy datatypes, all of that by Protege. After that we did made a set of fuzzy swrl rules to make better diagnosis for cases where there is uncertainty. What we can say is that fuzzy logic is method more accurate and give us results better then using SWRL alone but due the lack of data sets we can't say that our system is perfect and we have to:

Test our system with other larger data sets and from other fields too so we can make almost a generalization about the effectiveness of our approach.

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