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Theme

Implementation of a safety system for an alzheimer resident in a Smart Home

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We dedicate this work to
Our incredible parents,
Our sisters and brothers,
Our family,
Our friends and IT Family.

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List of Abbreviations

ADL	**A**ctivities of **D**aily **L**iving
AI	**A**rtificial **I**ntelligence
CoAP	**C**onstrained **A**pplication **P**rotocol
CPU	**C**entral **P**rocessing **U**nit
CSELT	**C**entro **S**tudi **E** **L**aboratori **T**elecomunicazioni
DC	**D**irect **C**urrent
DHT22	**D**igital **H**umidity and **T**emperature 22
FIPA	**F**oundation **I**ntelligent **P**hysical **A**gents
HTTP	**H**yper**T**ext **T**ransfer **P**rotocol
HVAC	**H**eating, **V**entilation and **A**ir **C**onditioning
IEEE	**I**nstitute **E**lectrical **E**lectronics **E**ngineers
IoT	**I**nternet of **T**hings
IR	**I**nfra**R**ed
IT	**I**nformation **T**echnology
JADE	**J**ava **A**gent **DE**velopment
JSON	**J**ava**S**cript **O**bject **N**otation
KQML18	**K**nowledge **Q**uery and **M**anipulation **L**anguage 18
ML	**M**achine **L**earning
OS	**O**perating **S**ystems
PC	**P**ersonal **C**omputer
PIN	**P**ersonal **I**dentification **N**umber
PLC	**P**rogrammable **L**ogic **C**ontroller
POS	**P**ersonal **O**perating **S**pace
RF	**R**adio **F**requency
RFID	**R**adio **F**requency **ID**entification
SOM	**S**elf-**O**rganizing **M**aps
SSHS	**S**emantic **S**mart **H**ome **S**ystem
TCP	**T**ransmission **C**ontrol **P**rotocol
UDP	**U**ser **D**atagram **P**acket
USB	**U**niversal **S**erial **B**us
WBAN	**W**ireless **B**ody **A**rea **N**etwork
WSN	**W**ireless **S**ensor **N**etwork

Introduction

"In all human affairs you have to risk to succeed. It is on the right assessment of the chances of gain and loss that great success depends", said Gustave Le Bon. Today, Information Technology is one of those fields where risks are often taken but where new perspectives are available to us. By developing this field and exploring its potential, an universe has been discovered. An universe in which distances, physical limits and even mental limits become less and less important and represent less and less of an obstacle. This allows us to accomplish things like Smart Homes, for example, which years ago would have been considered fiction.

During the last years, researchers have become increasingly interested in the case of Smart Homes, which has led to a huge development in this field. These ranged from electricity management (i.e., Smart Grids) to setting up a house capable of providing all the necessary comfort to make life easier for its inhabitants. But beyond the comfort aspect, very quickly the real potential of this technology was brought to light. It could not only be combined with several areas like medicine for patient follow-up, but it could also make us feel even safer at home by enabling a complete system dedicated to this.

Beyond the fact that the "smartness" paradigm is better known and that many works have been seen, the various achievements both at the international and local level (e.g., the creation of a Smart City in Sidi Abdellah, Algeria [1]) are only focused on comfort, ease of living or computer security, but the human security aspect is still very little studied. However, this aspect can be very useful for a large part of the population which is often forgotten; the elderly, patients suffering from cognitive diseases, or people who have difficulty moving around the house on their own.

The objective of this work is to make our contribution by implementing a system on a Smart Home that will ensure the safety of patients with Alzheimer's disease. Smart Homes have been adapted to many types of residents and patients, but the case of patients suffering from cognitive diseases is still given very little attention. Their implementation could completely change their lives and lifestyle, make them feel better at home, safe, but also be a treatment in its own right. This is the reason why, in June 2020, a fully dedicated intelligent village was opened in France which aims to maintain a certain number of cognitive capacities, and this while keeping as much as possible the daily landmarks of the person and his social links. For this project, we propose to set up a predictive algorithm which, as its name suggests, will make it possible to predict some dangers that may arise in the house and then make the necessary decisions for the safety of the inhabitant.

This dissertation is structured in four chapters as follows. The first chapter is dedicated to all the information necessary to understand this study. A brief introduction to the Smart Home, followed by an overview of the use of Artificial Intelligence in them, and a final part concerning network communication. In Chapter 2, we will present a general state of the art on different works on Smart Homes found in the literature. In Chapter 3, we start with a short introduction to Alzheimer's disease, followed by our proposal and its architecture. Finally, the last chapter is based on the implementation of our system and the discussion of the results obtained.

Chapter 1

Smart Homes knowledge

1.1 Introduction

We have always heard and imagined about Smart Homes and what they will be capable of. "*Use the imagination not to escape reality but to create it*", Colin Wilson said. This quote was taken to the word by some researchers who started to look for ways to implement it successfully. By adding this desire to the evolution of the technology, the implementation of Smart Homes has enabled to find a solution to many human's needs and concerns. This chapter covers all the basic notions concerning Smart Homes, Artificial Intelligence (AI), and the network and security technologies used in this context. After a short introduction to Smart Homes, we define Artificial Intelligence and make the link with the home environment. We also introduce the major networking technologies used in Smart Homes.

1.2 Overview of Smart Homes

This section provides a broad overview of Smart Homes: their definition and history, how they work, the reasons that led researchers to think about this alternative, and their main drawbacks.

1.2.1 Concept and definitions

Smart Homes have many designations: smart house, home automation, domotique, intelligent home, adaptive home, aware house, etc. However, they all mean the same thing: a system which offers a better quality of life by introducing automated appliance control and assistive services, and which performs tasks that are usually done in conventional houses by their inhabitants.

The notion of "Smart Home" was first introduced in the early 1980s when "the intelligent building" concept was also used. Yet, its definition has changed a lot over time. For example, in 1992, Lutolf [2] defined it as being "*the integration of different services within a home by employing a common communication system. It assures an economic, secure and* *comfortable operation of the home and includes a high degree of intelligent functionality and flexibility*". While in 2019, it was defined as "*a residence equipped with smart technologies aimed at providing tailored services for users*". But how "Smart" or "Intelligent" can a home be ? What makes a smart home different from a conventional home most of us still live in? A home is not smart because of how well it is built, how effectively it uses space, nor because it is environmentally friendly. What makes it smart is the intelligent implementation of consumer electronic devices, electrical equipment, the security devices aiming for the automation of domestic tasks, easy communication, and human-friendly control, as well as safety.

In conclusion, we can describe a Smart Home as an environment which is capable to react "intelligently" by anticipating, predicting and making decisions with signs of autonomy.

1.2.2 Brief history

Smart Home technologies have a much longer history than many may realize [3]. The germination of an idea of homes that could be smarter in the comfort and convenience they provide can be traced back at least to the 1890s and early 1900s, when wealthy people used the introduction of electricity to create homes with greater degrees of automation and levels of luxury, relaxation, and indulgence. The first "wired homes" were actually built by hobbyists in the early 1960s, this development is key to what is meant by Smart Homes. It was first used in an official way in 1984, by the American Association of House Builders, using the term "smart" for the intelligent consumption energy. The Smart Home concept was originally developed with the primary focus on providing convenience, improving security, and saving energy. Since the 1990s and 2000s, Smart Homes have again arisen as cornerstones of making homes both more efficient and lower in terms of energy consumption and carbon emissions, as well as a more pleasurable and enjoyable living environment.

1.2.3 Smart Home and its inhabitant

Smart Homes were at first designed for people with special needs. The architecture and operation of a Smart Home depends on these residents. The occupants can be classified into five groups: people with movement disabilities, older persons, people with low vision, hearing impaired people, and cognitively impaired people [4].

In the most basic representation of the home's operation, we find a set of sensors scattered around the house whose main purpose is to collect data about the inhabitants' actions. Once the data is recovered, it will be sent to the Home Server through the network, which can be wired or wireless. On data reception, the Home Server will make the decision on the action to perform by checking its database, and sends it to the concerned devices. In particular, a house designed for a person with mobility difficulties requires the installation of devices for assistance in mobility and manipulation, while the smart houses for aged people take into consideration changes in some of the organic functions of older persons. Smart houses for people with low vision and hearing impairments are equipped with special interfaces for communication.

1.2.4 Purpose of Smart Homes

Smart homes were initially developed for two main reasons. The first one is the technical part, which is the intelligent use of energy for ecological sustainability, while the second one is for a human reason that is to follow the dependant people and offer them this independence they desire so much.

1.2.4.1 Smart Grids

Electricity consumption in households has increased all over the world [5], individually it is not very significant but its true impact arises when it is summed up over millions of houses. That is why energy efficiency improvements and renewable energy increase are seen as the critical priorities to reach.

Needs for reliability, scalability, manageability, environmentally friendly energy generation, interoperability and cost effectiveness bring forward the necessity for a modernized and intelligent grid for tomorrow; a new, reliable, efficient, flexible and secure energy infrastructure, known as Smart Grid. The traditional electricity system structure consists of electricity flow in single direction that is from grid to thousands of consumers. But in a Smart Grid context, the traditional consumer is seen as a prosumer; simultaneously producer and consumer. The use of a residential smart metering brings the Smart Grid into our homes, transforming them into the Smart Homes of the future and allowing for more effective household energy monitoring and control.

1.2.4.2 Making life easier

There are many reasons why researchers have become interested in the use of Smart Homes [4]. Aging populations, the number of people who have difficulty moving as a result of the large number of accidents or ingrained illnesses, as well as cognitive diseases and many other illnesses that take away human dependency. When a person becomes dependent, it changes his life but also the lives of all those around him. Assigning a caregiver to each of them is impossible. The use of Smart Homes seems to have this concern which allows to offer the patient comfort, safety, and health monitoring (cf., Figure 1.1).

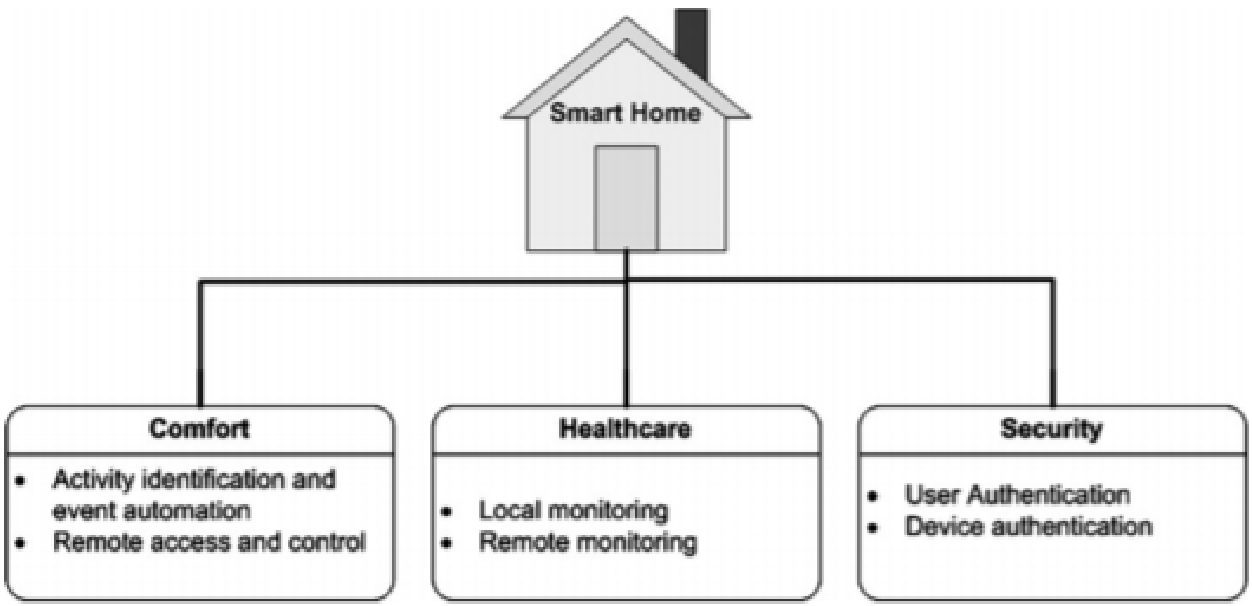

FIGURE 1.1: Purpose of Smart Homes [4].

1.2.5 Smart Home technologies

In the construction fields, a Smart Home is a dwelling environment that automates or controls all the devices by networking and sensor technologies [6]. The components used are mainly electronic components made to capture and quantify the data collected in the surroundings. The sensors are used to observe the environment and the devices provide proactive services with the goal to improve the occupant's experience.

1.2.5.1 Sensors

One of the most important elements in a Smart Home is the sensors, which collect the necessary data for the home operation. Inside the home, sensors are spread all over the house and are discretely attached to objects such as the toaster, microwave, door, etc. These sensors are activated when the occupant carries out daily activities, such as turning on the television, closing the microwave door, etc. The sensors are also triggered by the microwave oven. The data collected by these sensors can be useful for assisting and monitoring residents, usually elderly or cognitively impaired people living alone. In the home, we can find three types of sensors [7]:

1. *Direct environment components:* it is a set of sensors associated with a wired or wireless network, allowing the data transmission to a centralized monitoring system. They can be binary sensors, RFID (Radio Frequency IDentification) technologies, etc.;

2. *Motion detectors and pressure sensors:* they are used to detect the occupant presence and location throughout the house. Contact switches are considered as motion detectors, they are usually installed on the doors of a smart home such as the front door and doors of cabinets and appliances to provide information on the specific interaction that the occupant performs with objects and appliances;

3. *Video cameras:* they are considered as high-content sensors, which provide rich sources of information both for human observation and for computer interpretation.

1.2.5.2 Devices

A proper choice of the devices should give the user an integrated feeling of confidence for mobility, manipulation, communication, and environment control. The installed devices can be classified into five groups, depending on the functionalities we find in the house [8]:

1. Devices for automation and control of the home environment: automatic kitchen equipment, light and door controllers, home security devices, etc.;

2. Assistive devices which are external devices made to assist a person to make a specific task. We can find for example; robotic systems for movement assistance, devices for indoor navigation, devices for physical rehabilitation and fitness, etc.;

3. Devices for health monitoring of important vital parameters such as posture monitoring, behavior monitoring, monitoring of physiological parameters, etc.;

4. Devices for information exchange such as home network, information access and telecommunication systems, etc.;

5. Leisure devices such as virtual reality systems, etc.

1.2.6 Smart Homes disadvantages

A major disadvantage of this technology are certain social, ethical and legal barriers that impede its widespread adoption. These include the complexity of electronic health records, the lack of access to investment capital by health service providers, and the lack of standards for the exchange of clinical data. The fact that e-Health tools can reveal more than what the patients want also shows a privacy issue for the inhabitant.

On the other hand, Smart Homes can have a bad effect on human relationships, responses and interactions. This kind of technology will never be able to change an interaction with medical staff, but doubt and fear persist in the minds of some people. Informal caregivers may fear that a greater burden will be placed on them. Users may worry about a technology affecting their lifestyle, financial status, emotional and psychological well-being of family members. The final hurdle is the time spent by the patient learning how the technology works and how to use it.

1.3 Driving intelligence in Smart Homes

In this section, we provide an introduction to Artificial Intelligence (AI). A short definition was first introduced, followed by its use in Smart Homes and some examples of AI technologies.

1.3.1 Artificial Intelligence definition

Artificial Intelligence has undergone a major boom in recent years, both for researchers looking for ways to incorporate it into all their projects and for the general public. But defining Artificial Intelligence remains a rather complicated task, as it comes down to defining intelligence. The New International Webster's Comprehensive Dictionary of the English Language alone gives four definitions of Artificial Intelligence:

1. An area of study in the field of computer science. Artificial Intelligence is concerned with the development of computers able to engage in human-like thought processes such as learning, reasoning, and self-correction [9].

2. The concept that machines can be improved to assume some capabilities normally thought to be like human intelligence such as learning, adapting, self-correction, etc. [10].

3. The extension of human intelligence through the use of computers, as in times past, physical power was extended through the use of mechanical tools [10].

4. In a restricted sense, the study of techniques for more efficient use of computers by improving programming techniques [11].

Nevertheless, AI definition has also evolved enormously over time. At the present time, it could be defined as a field in its own right of computer science, which studies the understanding and imitation of human behaviour. Its main goal is to succeed in reproducing human behaviour then design some computer systems which can demonstrate some of the similar acts of human intelligence. The human behavior can be reasoning, perception, understanding, communication, design, reflection, learning and problem-solving, and other reflections.

1.3.2 Artificial Intelligence in Smart Homes

In the expression "Smart Home" we find the term "Smart", which can leave us thinking about intelligent reactions of the house by anticipating, predicting and making decisions with signs of autonomy. From a computational perspective, there is a natural association between this expectation and the use of techniques from AI. These techniques can be used to contribute, in many ways, to the development of Smart Homes. Multi-agent systems and Machine Learning are some examples of the techniques used.

1.3.2.1 Multi-agent systems

The advent of multi-agent systems has allowed Information Technology (IT) to make a significant impact. Agents are thus used in various IT disciplines, such as Artificial Intelligence, Big Data, Operating Systems, etc. They also allow the implementation of distributed, robust and intelligent applications.

Multi-agent systems have been described as "*a particular methodology for building agents. It specifies how the agent can be decomposed into the construction of a set of component modules and how these modules should be made to interact. The total set of modules and their interactions has to provide an answer to the question of how the sensor data and the current internal state of the agent determine the actions and future internal state of the agent. An architecture encompasses techniques and algorithms that support this methodology.*" [12], and as "*a specific collection of software or hardware modules, typically designated by boxes with arrows indicating the data and control flow among the modules. A more abstract view of an architecture is a general methodology for designing particular modular decomposition for particular tasks.*" [13]. In conclusion, multi-agent systems are systems composed of multiple interacting computing elements, known as agents. They can have common or conflicting agents. An agent is a piece of software that can run in autonomy to perform certain behavior.

Agents have three important capabilities. First, they are to some extent capable of some autonomous actions: they can work without the direct intervention of humans and has control over their actions and internal state. Second, agents can be social, they may compete to serve their interest but they can also communicate with humans and other agents to accomplish their tasks. Communication between agents can take place either directly or indirectly; directly through negotiation and communication, and indirectly by acting on the environment. Finally, agents are reactive, they perceive environment and can affect it [14].

1.3.2.2 Machine Learning

Over the last decade, Machine Learning has allowed us to make a big scientific leap. It is so responsive that without knowing it, we find ourselves using it every day for tasks as simple as driving cars, recognizing speech, doing effective web searches, better understanding the human genome, etc. Machine Learning can be defined in multiple ways:

> "Machine Learning at its most basic is the practice of using algorithms to parse data, learn from it, and then make a determination or prediction about something in the world." [15].
>
> “Machine Learning is the science of getting computers to act without being explicitly programmed.” – defined by Stanford University.
>
> “Machine Learning is based on algorithms that can learn from data without relying on rules-based programming.” – defined by McKinsey & Co.
>
> “Machine Learning algorithms can figure out how to perform important tasks by generalizing from examples.” [16].
>
> “The field of Machine Learning seeks to answer the question: How can we build computer systems that automatically improve with experience, and what are the fundamental laws that govern all learning processes?” [17].

By combining all of the above definitions, we can conclude that in Machine Learning, a program is responsible for performing certain tasks by making decisions and predictions/forecasts based on data acquired over time.

Machine Learning is used in several domains like robotics, virtual personal assistants and Smart Homes. Rather than a well-defined field, Machine Learning refers to a broad range of algorithms like learning and prediction algorithms.

1. *Learning algorithms:* they are integral methods of Machine Learning. They are algorithms used for data processing. From the collected data, these algorithms allow to extract appropriate models for an application in a new situation. The objective is to adapt a system to a specific input-output transformation task [18]. Learning algorithms work with a careful selection of features that result in a better model. These characteristics are often called independent variables, explanatory variables or predictors. They are measurable heuristic properties of phenomena [19].

2. *Prediction algorithms:* today, prediction algorithms are a common part of our lives. We live in an era where data is abundant and computing power is powerful and cheap. This data is then combined with statistical algorithms and Machine Learning techniques to identify the probability of future outcomes. Prediction algorithms are based on a collection of recorded states and transitions. The recorded states contain the values for each device, and the transitions states the values for each device before

and after an event has occurred and when it occurred. The algorithm determines the probability that the event will occur [20].

1.4 Home-networking technologies

A smart home is made up of multiple components that constantly communicate with each other. When we talk about communication, we automatically think of networks. In this section, we define what a network is and how it is used in Smart Homes, while presenting the most commonly used communication protocols.

1.4.1 Network definition

Water, air and food are all necessary needs for human survival, but beyond that there are other needs such as communication. We communicate constantly, and the methods we use to share ideas and information are changing and evolving constantly, as well. If previously the human network was limited to face-to-face conversations, today's technology evolution is incessantly extending the range of our communications.

In IT, a network can be represented by a road connecting several computers; "*the fabric that ties business application together*" [21]. Its main function is communication and file sharing between computers. For a network to be operational, all the devices that make up the network must be connected, either by wired or wireless technologies. While early data networks were limited to the exchange of character-based information between connected computer systems, they have evolved into modern networks that can support a wide range of applications, transfer audio and video, and operate on many types of physical media. Networks are evolving but one thing still does not change, networks must take into account four characteristics if they want to meet user expectations, namely, fault tolerance, scalability, quality of service and security. Data networks, originally intended to transport information from one company to another, have now acquired a new purpose; improving the quality of life for people all over the world.

1.4.2 Basics of network communication

Communication begins with a message, or information, that are sent from one individual or device to another. Communication takes place through different methods, but all of these methods, whether electronic or not, have three elements in common. The first element is the source of the message, or the sender. Message sources are people, or electronic devices, that need to send a message to other people or devices. The second element of communication is the destination or recipient of the message who, upon receiving, interprets it. The third element, called a channel, is the medium that provides the path over which the message can travel from source to destination.

1.4.2.1 Network topologies

The term topology refers to the physical organization or arrangement of the hardware making up the network [21]. So, it is the graphical representation of a network infrastructure, which is used to define the type of the network equipment, the nature of the cabling, the management of the network and the way they have been interconnected. A topology facilitates the identification of possible bottlenecks in network traffic, which will allow to focus the traffic analysis data collection on areas where improvements would have the greatest impact on network performance. There are two types of topologies:

- *Physical topology:* it describes how different nodes are connected to each other in the physical world.
- *Logical topology:* it describes how data moves through the network.

The way in which the different topologies are used makes it possible to understand the capabilities of the different networks and can also help to determine the protocol that will match. There are five initial topologies but in some networks, we can find combinations between the different topologies. The basic topologies are: bus, star, ring, mesh and hierarchical/tree, as can be seen in Figure 1.2.

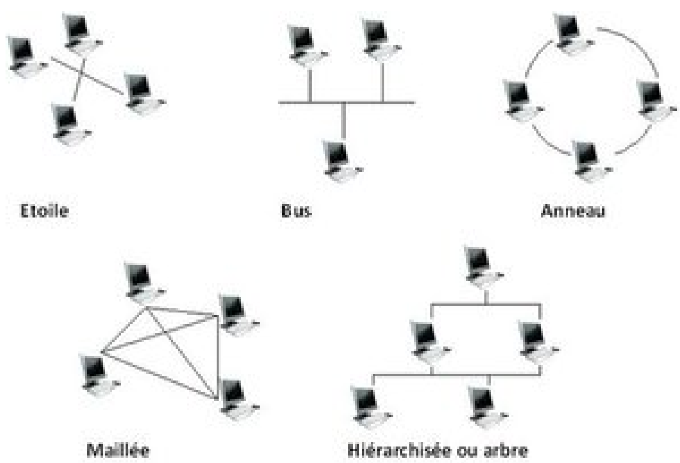

FIGURE 1.2: Types of network topologies [21].

1.4.2.2 Network protocols

Communications in networks are governed by rules called protocols. Successful communication between hosts on a network requires the interaction of many different protocols. A protocol suite is a group of protocols that are associated with each other to describe the specific requirements and interactions necessary to perform a communication function. These protocols are implemented in software and hardware loaded on each host and network device. In general, protocols do not indicate how to perform a particular function. They only indicate which functions are required for a specific communication rule but not how these functions are to be performed. The definition of a protocol includes:

- Type of exchanged messages;
- Format of message content;
- Communication rules.

TCP (Transmission Control Protocol) and HTTP (Hypertext Transfer Protocol) are some examples of protocols.

1.4.3 Enabling Smart Homes with networks

A smart home has many needs; an interface, a security system, but it must also contain a network and a set of protocols. Smart Homes use wireless technologies to facilitate the transfer of commands to the various devices of the house. Over time, a large number of protocols have emerged, whether they are adapted or created specifically for Smart Homes. The most used and known are: X10, INSTEON, ZigBee and Z-Wave.

1.4.3.1 X10

X10 is one of the oldest protocols from which many others have subsequently drawn inspiration. It was the first to combine wired and wireless technology in Smart Homes. However, X10 has a major drawback; messages are only transmitted one at a time, multiple X10 signals at a time can lead to decoding and loss of information. X10 is still on the market, and many homes are still equipped with this technology. It remains inexpensive with a wide range of devices available [22].

1.4.3.2 INSTEON

INSTEON was developed by Smartlabs Incorporation and was designed to replace the X10 protocol. It is distinguished by the use of wireless and electrical lines. It allows devices, whether sensors or switches, to communicate using the power line and/or radio frequency. Another advantage of INSTEON is its compatibility with X10 devices. INSTEON and X10 are not similar, but the INSTEON chipset driver has the ability to respond to X10 messages, and can therefore communicate with X10 devices. Site data transmission is at 1131.65 KHz for power lines and 904 MHz for wireless devices [22].

1.4.3.3 ZigBee

ZigBee is a low data rate, low power consumption and low cost wireless networking protocol developed by ZigBee Alliance. It was designed for home automation, building automation, and other applications in the building industry. It was developed to become the world standard for control/sensor networks. ZigBee is an IEEE 802.15.4 based specification which defines support for simple devices that consume minimal power and typically operate within the 10m Personal Operating Space (POS). It is based on the use of a self-organized, multi-hop, reliable mesh network with long battery life [23].

In the field of home automation, the ZigBee protocol easily makes a place for itself. First, because it provides a reliable method for intelligent detection inside and outside homes, targeting domestic lighting, air conditioning, tap water, etc. Next, because it is easy to install thanks to the large number of sensors making use of battery-powered to guarantee a long service life without wires. A wireless home network function based on ZigBee is particularly powerful. Users can enjoy the home automation, save costs, and provide safety and comfortable life to people. All these functions enable ZigBee to offer broad-range wireless networking applications.

1.4.3.4 Z-Wave

Z-Wave is a wireless protocol for home and commercial automation equipment. It was developed by Zensys. It allows the operation of all the main electrical appliances in the home such as lights on/off, HVAC (Heating, Ventilation and Air Conditioning), kitchen, televisions and home security.

The special feature of Z-Wave is that it enables the reliable transmission of short messages from the control unit to one or more devices in the network with a minimum of noise. Each device designates a node and belongs to the network that uses a Z-Wave protocol. Communication between the nodes is carried out using Radio Frequency (RF) technology. RF allows nodes to be inserted or removed from the home network and minimizes installation costs compared to the wiring required. In addition, it uses a mesh network configuration, which means that each device in the network sends and receives control commands through walls or floors, so it makes Z-Wave covering all areas of the house. Z-Wave contains a VERA Internet gateway, where users can create scenes, events and timer settings to personalize the electrical devices as they require. The best feature of Z-Wave devices is their cross compatibility among different branded systems. Each Z-Wave device has a unique network ID (Identification) and each network has a unique identification, thus making the system secure [24].

1.5 Conclusion

Smart Home technology is on the rise. Many factors ensure that in the future all of our houses will become intelligent. In fact, Smart Homes succeed in meeting all the needs of a human being related to comfort and security. Moreover, the combination of new networks technologies ranging from communication protocols for sensors to AI technologies such as Machine Learning and multi-agent architectures makes it a very interesting subject. In this first chapter, we have given an overview of Smart Homes, describing their functioning, the technologies used and the why of the how. We have also provided a short introduction to AI and networks communication technologies used and that are relevant for the future chapters.

Chapter 2

State of the art on Smart Homes

2.1 Introduction

After the concept of Smart Homes was introduced and its potential discovered, a great deal of research has came to light. All this research was aimed at exploiting the potential of Smart Homes to the fullest. Data security, comfort and the inhabitant's security have been the subject of much discussions and the field of many evolution and improvement through research. Chapter 1 allowed us to understand the concept of Smart Homes in general and how they work. In this chapter, we provide a detailed description of how it has been exploited through researches. A state of the art is presented, gathering some relevant research works on the safety and comfort of the inhabitant in a Smart Home. After working on several articles, we have come to this classification : Article which were Application-based solutions, Article with solutions based on voice and gesture commands and finally solutions based on machine learning algorithms. After that, we discovered the classification of Vavilov et al. [25] which looked like our reflection, and that is why we have reused his denomination. Our state of art articles were then classified into three main categories: sensor-based, directive-based, and user-behavior-based approaches.

2.2 Sensor-based approaches

The home is equipped with different types of sensors measuring several parameters of the environment like temperature, somebody's presence, etc. (e.g., motion sensor and RFID reader). Sensor-based systems are usually used for complex and smart implementations; the light turns on when a sensor detects someone in the room, for instance [25].

2.2.1 Improving Smart Home Security: Integrating Logical Sensing into Smart Home

Jose and Malekian [26] have proposed to put logical sensors in places around the Smart Home to be able to detect danger, like intrusion or fire. In their opinion, the ideal way to improve the security of a Smart Home against intrusion is to always recognize the inhabitants and identify their position in the home, of course, without bothering them.

The proposed algorithm works with states; the home can be either empty or occupied, and the door opened or closed. It helps to determine the different scenarios that can occur at access points by analysing multiple proximity and motion sensor values before and after the door is opened or closed, the time period between the initial and final state of the door, and the number of sensor values considered for the initial state and after the final state. The logical sensing algorithm can differentiate between normal and attack (i.e., intrusion) behaviours in the access points. The latter are of two types; primary ones, which are used to go inside and outside the house (i.e., front door, back door, etc.) and secondary ones, which can also be used to enter/exit the house, but are rarely used for this purpose (e.g., windows, balcony door, etc.).

For the primary access point, motion and proximity sensors are placed near the front door inside the home, in such a way that every entry to the house is detected. If the home is occupied and the inhabitant opens the door, the motion and proximity sensors are triggered before it is opened. Likewise, when the home is empty and someone goes in, the motion and proximity sensors are triggered after the door is opened. All this gives different combinations of states to determine whether it is the inhabitant/safe person entering the home or an intruder. For example, if the door is open and the user steps out and closes the door behind him without triggering the motion and proximity sensors after closing the door, in a home occupied by a single person, the state of the house changes from occupied to empty. When a home changes its state from empty to occupied, the identity of the entering person has to be verified. The verification technique can vary from digit PIN (Personal Identification Number) to fingerprint or biometric recognition (i.e., depending on the user). There are several situations that can lead to identity verification and if the user fails it, the home activates then defensive measures such as alarms.

For the secondary access points, the sensors are placed similarly to the primary access point, to determine if a window or balcony door is opened from inside or outside. Under normal circumstances, it is always from the inside. In case the home is empty and a window or balcony door is opened, the system triggers intrusion defence mechanisms without waiting for identity verification. But if the home is occupied, and it is opened from the outside, a warning is triggered and the system asks the user to confirm his identity. There is also a prevention system in case the user goes out (i.e., home state changing to empty) leaving a window open, an alarm warns him that the window must be closed.

The proposed system also observes the user's bed, with force sensors placed underneath the mattress. In a single person occupied home, if any of the access points changes state while the user is in his bed, this indicates an intrusion. During the night (i.e., when the user is supposed to sleep), the algorithm activates an intrusion defence mechanism without waiting for identity verification. During the day, a warning indicating the change of state of the access point is triggered and the user is asked to confirm his identity. In addition to intrusions, the system also detects potential fires. During home fire, the carbon monoxide and the ambient temperature levels in the area of fire go up, and inversely, the humidity in and around the area goes down. This is why, sensors have been placed in front of the areas at risk, and every 12 seconds, new data are compared to the old ones to detect an anomaly. With this process, if a fire is detected without the sensors noticing a change, then it is probably a fake alarm and an attacker is trying to sneak inside the home. In fact, during a fire alarm, all the entrances are unlocked, so the user is warned of a possible attack.

The system was tested during one month and detected all the 305 changes of front door status, and managed to eliminate the intermediate states and reduce them to 190 changes.

2.2.2 Semantic Smart Home System: OntoSmart to monitor and Assist habitant

The populations are older and older, and their follow-up is more and more complicated. Quickly, a problem appeared: how to improve the quality of life and the follow-up of dependent people? Researchers began to focus on Smart Homes. This new technology could be the solution, but it still has too many drawbacks to be implemented (e.g., heterogeneity of the systems, dependent vendors, the difficulty of extensions of the system, etc.).

In this work [27], the authors have based themselves on two of the major problems affecting Smart Homes, namely, heterogeneity and interoperability. Semantic techniques have been introduced to counter the concern of system interoperability; ontology was chosen. It gives us a description of the inhabitant, his environment and the activities he has performed. The second problem, which is heterogeneity results from the use of several nodes/components that are completely different from each other and may come from different manufacturers, making a possible connection between them complicated. To address this problem, a multi-agent architecture where each agent can invoke another agent was implemented.

When monitoring a patient, an infinite number of parameters can be taken into account. In this case, for the patient's side, the system considers only the heart rate, the posture and his location. Whereas for the home, indoor localization, ambient parameters, air condition/heater are taken into account. The proposed OntoSmart system consists of two clusters; a Wireless Body Area Network (WBAN) and a Local Cluster. The WBAN consists of a set of sensors that will be directly connected to the patient's body and will collect all the necessary data and send it to the local server via a Data Collector Agent (Cluster Hub), which in this case is the patient's phone. The communication between the Cluster Hub and the local server is done by JSON (JavaScript Object Notation) messages. The purpose of the WSN (Wireless Sensor Network) Cluster, or Local Cluster, is to monitor the home level: temperature, location, etc. Concerning the ambient parameters, they will be connected to the resident's Smartphone, so the exchange with the local server will be through JSON messages. The rest of the communication will be via PLC (Programable Logic Controller), following the TCP Bus Mode. The last component of this architecture is the Semantic registry, or Remote Semantic Storage and Management Server. It deals with the registration of all SSHS (Semantic Smart Home System) ontologies implemented using different types of agents.

Two mobile applications have been developed that allow the patient and his family to monitor his vitals. The first one is completely dedicated to the patient. During the first use, the patient will connect thanks to his Gmail address and will configure everything concerning his relatives and his location in the house, etc. At the end of the initialization, he will see all the parameters displayed on the screen. The second application is dedicated to the patient's relatives, who will have continuous access to his constants through continuous CoAP (Constrained Application Protocol) GET requests sent to the remote server. In case of concerns, notifications will be sent to the relatives. Two types of notifications have been configured; abnormal heart rate notification and fall detection notification. To avoid false alarms a timer of 1 minute has been introduced during which the patient will be able to cancel the notification.

The proposed system was first tested on two different patients in two different WSNs, with one parent per patient and after making sure that the ontology was well ranked or the reliability of the system to provide services based on the needs and requirements of the occupants was realized. Then it was tested on two patients in the same WSN, and the ontology was classified without any ambiguity. This ensures the reusability of the proposed system by more than one occupant without any confidentiality problem thanks to the use of Gmail account for authentication. The use of Smartphones is a solution to the problem of sensor lifetime, but the sensor falsifies the results regarding the patient's posture or risk of falls.

2.3 Directive-based approaches

This category concerns the ability to manage or control the house using a simple mobile device or via the Cloud, for example. However, to be fully controlled, the home must have a decent amount of connected devices, and managing all of these home devices requires significant effort from the user, at least for input of directions. It can be simplified by automating a few tasks; for instance, a user consequently needs opening the garage door and turning on the light when he/she returns home after work.

2.3.1 A Smart Home Appliance Control System for Physically Disabled People

A Smart Home is a connected home, which uses a network to control home functions for a better quality of life, for example, control lighting. Usually, the control is done via the resident's phone, because of its ease to communicate wirelessly and through programmable applications or a centralized PC (Personal Computer) connected to the home. This kind of solutions presents a problem; they are not necessarily adapted to physically disabled people.

Hence, the authors [28] have thought of a new solution where the control will be easier for a large number of people. They have proposed a voice control system through a digital assistant. The whole architecture proposed by the authors is centered around a well-known digital assistant: Google Alexa. They have associated it with functional and intelligent equipment such as smart cameras. For the identification of the inhabitant, a DeepLens is used so that once it has identified the voice of the person, Alexa will be activated. Resident has been selected with a walking disability and has a regular (i.e., non-smart) stove, slow cooker, lamp, fan, microwave oven, toaster, refrigerator, a washing machine, and a toaster oven. Three life scenarios have been proposed. The first one provides a description of the interaction between Alexa and the different connected devices; four sockets are connected to Alexa that can be turned on or off via a voice command. The two remaining scenarios integrate the security of the inhabitant. In the second scenario, the resident has an overview of the entire house via the use of smart cameras and a simple voice command. In the last scenario, another type of resident has been added; an elderly person. The parameter considered in this case is the risk of fall. The DeepLens can be configured to detect a fall so that Alexa warns an external person associated with the resident's location.

Figure 2.1 shows the third scenario using a DeepLens video camera that monitors, detects and responds to unpleasant incidents. The proposed solution is quite expensive and involves very specific devices, and therefore not available for everyone. It is also not adaptable to deaf-mute people since all control is done by voice.

FIGURE 2.1: Representation of the third scenario [28].

2.3.2 Smart Home Appliance Control System for Physically Disabled People Using Kinect and X10

Science and technology are becoming an essential part of human life. Over the years, technology has evolved and its interaction with humans has also evolved to perfect the concerns that humans may encounter in their lives. The dependency of elderly people and those with disabilities is a global issue that affects them not only, but also their families and friends as well. Smart Homes then appeared as a possible solution to this problem, even if they remain relatively expensive and are not well-suited to them.

In this work [29], the authors have addressed both concerns by proposing an inexpensive and easy-to-use architecture. The proposed architecture is composed of five components. The first component is the Kinect that takes care of user tracking, making it possible to detect all gestures or any possible vocal commands he/she emits. In this architecture, the Kinect stops at the track of the elbow and the hand of the user. The second component is a CPU to which the Kinect will be connected via a USB port. This will retrieve all the data collected by the Kinect and make the necessary decisions thereafter. Once the CPU has made the decision, it transmits it as well as the address of the module to be activated via the third component, namely, the X10 modules. Communication with X10 can be done in several ways. The X10 transceiver modules are connected to the USB ports or the serial ports of the CPU. X10 receiver modules are plugged into electrical outlets and do not require any further connection to the transceiver module as they can communicate via existing wires in any home, as long as they are under the same load as the transceiver module. The transmitted data will arrive at the desired address, which is represented by the fourth component, namely, the electrical and electronic devices, as shown in Figure 2.2.

The developed prototype has been able to show its effectiveness after several tests. The

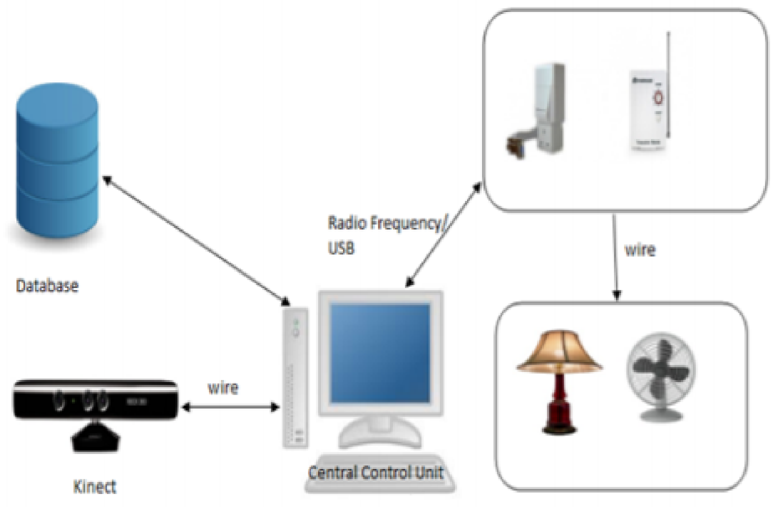

FIGURE 2.2: Interconnection of devices [29].

first subject of the test is the speed of response of the house to user commands, which displays relatively good results of 3.75s. It is calculated from the time necessary for the Kinect to detect an event, the communication time between the Kinect and the CPU, and finally, the propagation delay of X10 devices in the system. As second performance factor, they tested the usability of the system. For this reason, ten people were taken in different age groups and with different disabilities, and were asked to assess the house. In the end, 70% determined the house easily adaptable and 60% confirmed its usefulness for people with disabilities. The architecture set up is adaptable, it gives a secure and independent life and provides a comfortable and interactive smart home system for people with disabilities, but it could be improved by the location of the Kinect everywhere in the rooms.

2.4 User-behavior-based approaches

Some manufacturers have suggested several products that analyze user behavior, such as for targeted advertising. Analyzing the behavior of the inhabitants and making decisions on the basis of this analysis can therefore be interesting and considered as an additional approach for smart homes appliances.

2.4.1 Anomaly Detection in User Daily Patterns in Smart-Home Environment

Novák et al. [30] have proposed a semi-supervised clustering model that uses the SOM (Self-Organizing Maps) neural network. This algorithm learns the user behavior pattern and detects anomalies by comparing it with the learned pattern. The objective is to construct areas in a two dimensional space given by vector (s, d) of normal or expected behavior, while the remaining part of this two dimensional space is marked as anomalous. SOM needs some input data, which are collected by sensors all over the smart house:

- *Location*: where the action occurs;
- *Start time*: when the action starts;
- *Duration*: how long the action takes.

In addition to this input data, there are parameters required by the model to be able to correctly learn a behavior pattern:

- I, J: a size of the neurons lattice;
- λ: a number of iterations used for learning;
- α: a learning rate;
- τD: the minimum amount of time an action should last.

The algorithm has two phases, namely, the learning phase and the recognition phase. In the learning phase, a set of locations L is defined depending on the location of the sensors, and a set of activities A recorded during a learning period. Every activity $a_i \in A$ is a tuple (l_i, s_i, d_i) where:

- l_i is location of a sensor;
- s_i is start time of an activity;
- d_i is duration of an activity.

SOM is executed on each location to obtain clusters C_i of "normal" activities. In the recognition phase, two types of activities are used, real activities and timestamp activities. The timestamp is used to identify if the current activity is not unusually long, for example if the user loses consciousness and is unable to move. By verifying that the activity does not belong to the previously constituted cluster, the following anomalies are recognized:

1. *Unusual activity:* for this type of anomaly, only real activities are considered. When such an activity does not belong to anomaly cluster in that particular location.
2. *Unusually long activity:* for this type of anomaly, only timestamp activities are considered.

3. *Unusually short activity:* for this type of anomaly, only real activities are considered.

The experimental study was realized using real data gathered in a smart home system from Valdespartera Living Lab [30]. The simulator was used for a period of two months (60 days), including 37 working days and 23 free days. Free days are too noisy without any regular patterns, that is why only working days are used. 20 of the 37 working days were used to generate a training dataset, and the rest were used for testing. The accuracy ranges from 83.8% for unusually short activities to 99.1% for unusual activities. The model incorrectly recognizes anomalies, which differ only in 20 minutes or less from standard behavior.

2.4.2 Smart Home User's Behavior Prediction

Platonov et al. [25] have proposed to analyze the user behavior during a period and predict which action he/she will take and when, so that the system performs it for him/her. The purpose of this method is to make user's life easier in terms of futile tasks, and to focus on more important actions. The authors modified Dmitry's algorithm [25] for the prediction of TV channels based on the viewings analysis to adapt it to other actions that can be predicted in smart homes, and gave us two solid examples, lighting management in a room and air conditioning.

For light management, the system must be able to turn on the light at the right time and at the right intensity on a day D. For this, the user's actions are observed and the lighting level, the start time and the duration are recorded for a period of 10 days before D-day. After that, a "rate" is calculated for each event, by multiplying two components, the first one depends on the duration of the event (e.g., from 0.001 for the shortest duration, and 1 for the longest), and the second depends on the interval between the observation day and the D-day (e.g., 1 for D-1 and 0.01 for D-10). These rates are then added together according to the intensity. At the end, a probability for each level of intensity is assigned.

For air conditioning management, unlike lights, there are not one but two parameters to consider; temperature and blowing mode, but the process remains the same. A rate is calculated for each event (i.e., temperature and blowing mode), and summarized according to the blowing mode to get their probabilities, at the same time. A probability for each temperature is given, the product of these two probabilities gives the final result.

With these two examples, the authors were able to demonstrate that simple prediction algorithms such as TV channel prediction can be tailored to the needs of the user in a Smart Home, which will help them focus on other activities.

2.4.3 Decision support for Alzheimer's patients in smart homes

More than 18 million is the number of elderly people diagnosed with dementia in 2008 [31]. Among this dementia, the most found is none other than Alzheimer's disease. Patients with Alzheimer have progressive cognitive deterioration; they suffer from difficulties to accomplish simple activities of our daily life. To address this problem and make life easier for people with this disease, the authors [31] have proposed a solution based on Smart Homes: a probabilistic learning approach to characterize the behavior patterns of multi-inhabitants of Smart Homes. They aim to learn inhabitants activity profile thus to predict tasks or actions to help patients perform ADLs (Activities of Daily Living) independently, such as supporting their desire to stay at home longer. To this end, they have proposed a snowflake data model to represent the activities data in Smart Homes, where sensor data is stored in the HomeML (Home Modelisation Language) structure. A learning algorithm is developed to derive behavior patterns for multi-inhabitants in a form of probability distributions over activities in different contexts. The obtained patterns are then used to assist inhabitants to complete an activity as needed, by predicting the most likely upcoming action in the activity, based on partially observed low-level sensors information. The Smart Home is represented by a snowflake schema based on four major points:

- Person: since we have several inhabitants, it represents all the data concerning the different persons;
- ADL: the set of activities we are used to do such as eating, preparing a meal, etc
- Episode: sequence of low-level sensors activation during an activity;
- Time: the time or moment at which the activity is performed, for example, in the morning.

The inhabitants behavior patterns are characterized by a probability distribution over different activities. From a statistical standpoint, data are a random sample from an unknown population represented by a joint probability distribution [31]. Data analysis is performed to identify the corresponding probability distribution that is most likely to have generated the data. The authors have proposed a learning algorithm using Maximum Likelihood estimation given their sampled activity data in the lab. Maximum Likelihood is a popular statistical method used to reveal parameters of the underlying probability distribution [31].

To evaluate in a controlled way the performance of the learning algorithm under various aspects, the authors generated realistic simulation data based on the patterns shown in the real data using Matlab where the chosen environment was 'making drink' activities. More specifically, they identified three different activities: ADL1= "making a cup of tea", ADL2= "making a cup of coffee" and ADL3= "making a glass of juice". Two users activities are monitored and studied for a period of time in the laboratory. An interface has been designed to collect Person and ADL labels for their activities. The users were asked to select their names and the activity they intended to carry out. The results showed that the learning algorithm can achieve good performance without using too much expensive training data. Regarding the prediction, the more observations we have, the more accurate the predictions are, as assumed. However, when it comes to only two observations, performance is significantly improved compared to a single observation.

2.5 Comparative study

In the previous sections, a lot of works have been described. Each work was intended either to secure the life of the inhabitant in smart houses or to make his life easier. For this, each one brought its own solution based on different technologies. After presenting them, we made a small comparison summarized in Table 2.1, where we took into account: the type of solution, whether it is based on comfort or security, the approach chosen by the authors, the type of inhabitant chosen, the parameters taken into account in the house, the disadvantages of this solution, and finally, the type of technologies used (i.e., sensors, devices, etc.).

2.6 Conclusion

In this chapter, we have made an overview of what has been proposed in the literature. Several research works were treated on the possibilities that a Smart Home offers to its inhabitants from the point of view of comfort and security, and which ended with a comparison table. From the data collected, we were able to understand the subject and draw a path that led us to our problem: the safety of an inhabitant with Alzheimer's disease in a Smart Home. The problem as well as the solution we propose will be explained in detail in the next chapter.

Reference	Classification	Handled problem	Selected approach	Type of inhabitant	Parameters	Disadvantages	Equipment
Platonov et al. [25]	User-Behaviour based	Comfort	Prediction	/	- Level of intensity - Temperature - Blowing mode	Not accurate	Not mentioned
Jose et al. [26]	Sensor based	Security	Prediction algorithm to detect an intrusion or a fire	Undefined	- Detection of intrusion - Risks of fire	Analyzes user behavior on the access points only	- Logical sensors - Proximity and motion sensor
Nachabe et al. [27]	Sensor based	Comfort and Security	Ontology and multi-agent architecture	Elderly people	- Abnormal heart rate - Fall detection	Using a telephone does not reliably determine the risk of falling or the patient's posture	- Phone - Heart rate sensor - Acceleration sensor - Indoor localization sensor - Ambient parameters sensor
Mtshali and Khubisa [28]	Directive based	Comfort	Voice control system	Physically disabled people	Risks of fall	- Expensive - Requires specific devices - Not available to everyone - Not suitable for deaf-mute people	- Smart camera - Digital assistant - DeepLens
Iqbal et al. [29]	Directive based	Comfort	Gesture and vocal control system	Physically disabled people	- Speed of response - Usability of the system	Only works in a room where the Kinect is located	Kinect
Novák et al. [30]	User-Behaviour based	Security	Neural Network	Undefined	- Size of the neurons lattice - Number of iterations used for learning - Learning rate - Minimum amount of time for an action	The model does not recognize anomalies that differ by 20 minutes or less from standard behavior	Location sensors
Zhang et al. [31]	User-Behaviour based	Comfort	Probabilistic learning approach	Multi-inhabitant with an Alzheimer's patient	Number of correctly predicted classes	Requires a maximum of observation for an accurate prediction	Two types of binary sensors: - Movement detector - Contact switch

TABLE 2.1: Summary of the reviewed works.

Chapter 3

Securing a Smart Home using a prediction algorithm

3.1 Introduction

The first two chapters helped us get started and better understand the world of Smart Homes. After discovering some of what was being done in the literature, the idea of working with an Alzheimer's patient began to interest us. In this chapter, we outline the reasons for choosing a patient with Alzheimer's and a description of the solution put in place to allow them to live safely in their Smart Home.

3.2 Challenges and motivations

Smart Homes have always been a way to make life more comfortable for people with disabilities. But what about home security? Information security is the subject of much research: creation of new protocols, adaptability of security solutions for IoT (Internet of Things) or ad hoc networks, etc. and among them many are used and are perfectly suited to Smart Homes. However, the safety of the inhabitants is very rarely taken into account. If we want to help a person regain a semblance of independence, his safety remains a significant point. An accident happens quickly and every minute after the accident can have consequences and be fatal. Of all the categories, people with cognitive illnesses receive the least care. Alzheimer's disease has always been in the news and we all know the consequences. People with Alzheimer's disease often have trouble accepting their loss of autonomy and often end up changing their behavior as a result: withdrawal or, on the contrary agitation, screams, verbal or even physical violence [32].

The main symptom of Alzheimer's disease is memory loss. A home accident is common, but for someone who has lost their bearings, it is even more frequent. Our objective is, beyond making life more comfortable at home, to guarantee the safety of the inhabitants. To do this, we must identify any behavior that could be dangerous and put an end to it before the consequences arise and endanger the life of the inhabitant. If the accident does occur, however, we must find a way to contact emergency services as quickly as possible.

3.3 Resident diseases

In what follows, we explain what Alzheimer's disease is, the different treatments available, and describe how our work will help people with this disease.

3.3.1 Cognitive diseases

The term cognitive refers to all the psychic processes related to the mind such as memory, learning, coordination, perception, reasoning, and so on. A cognitive impairment is the alteration of one or more of the preceding points. This is a set of symptoms of brain origin that are commonly found in neurodegenerative diseases such as Alzheimer's disease. It can have a medicinal, psychiatric, neurological, etc. origin. Indeed, it is caused by aging, illness or brain trauma. Cognitive disorders are found to varying degrees in many neurodegenerative diseases and, depending on the patient, the disorder can be mild or severe or progress to dementia. In the case of a severe disorder, the reduction in capacity leads to difficulties in carrying out certain activities of daily living alone (e.g., running, going out, making phone calls, etc.). On the contrary, people with a mild disorder can still perform these activities of daily living on their own [33].

3.3.2 Dementia

Dementia is not a specific disease but rather a general term for a decline in mental abilities severe enough to interfere with daily life [34]. This is a much more severe deterioration in cognitive function that worsens over time. It can cause changes in memory, language skills, judgement and decision-making ability, disorientation and personality transformation [35]. During normal aging, some people lose things or forget details, but in dementia, the memory is of the whole event. Memory of recent events is impaired; learning and retaining new information becomes difficult. Language disorders especially a lack of words, mood swings and personality changes develop. Patients may have more and more difficulty with daily activities (e.g., managing their cheque book, finding their way, remembering where they have placed their personal belongings) [35].

Dementia impairs cognition overall. The onset is progressive, although family members may report a sudden start: when daily functioning is disrupted. Short-term memory impairments are often the first sign. Initially, the first symptoms may not be distinguishable from those of an age-related memory impairment or mild cognitive impairment, but with progression they become apparent [35].

Alzheimer's disease accounts for 60-80% of dementia cases [34].

3.3.3 Alzheimer disease

Alzheimer's disease is a type of dementia that causes problems with memory, thinking and behavior. It is a progressive disease whose symptoms gradually worsen over the years until they interfere with daily tasks [36]. The most common, well-known and noticeable symptom is memory impairment. However, other symptoms remain evocative of this disease; at the onset of the disease, we may also observe language disorders or vision problems (e.g., reading, locating objects), and disorders of the executive functions (e.g., programming, sequence of realization of a goal, etc.). The problems of orientation in time and space are also revealing; people who develop the disease no longer know their place in time [37].

Despite the fact that Alzheimer's disease is known and responded to, no treatment has yet be found. Existing treatments are only there to slow the progression of the disease and improve the quality of life of the people who suffer from it and of the caregivers who support them [36]. Today, a global effort is underway to find better ways to treat the disease, delay its onset, and prevent it from growing. There are two types of treatments prescribed to patients, which we describe in the following.

3.3.3.1 Medicinal treatments

Four drugs are available on the market. Ideally, the family, the patient and the specialist will see an improvement, with a better quality of life and improved cognitive performance. But more often there is a slowing down of the evolution of the disease and a decrease in some behavioral problems [38].

3.3.3.2 Non-medicinal therapy

The environment, the psychological approach and the social aspect are adapted to preserve the capacities of each patient as long as possible. Non-drug care has several advantages, regardless of the actions taken. They also have one thing in common; they help the patient to communicate and help the family and caregivers to adapt their behavior. The goal of non-medicinal therapy is to encourage the patient to work on his memory and stay in touch with his entourage. This can be done by [38]:

- Cognitive simulations where a patient is made to relive past events;
- Speech therapy to maintain communication with the patient with language difficulties;

- Physical therapy to prevent the risk of falls but it can also have an effect on certain aspects of behavior;
- Music therapy, aromatherapy, animal assisted therapy, etc. to improve certain aspects of behavior and prevent patient isolation.

Based on this treatment, numerous village design projects have been developed, such as the one in Amsterdam or the new village of Landes, France, which was scheduled to open in June 2020. The village « Alzheimer » of the Landes [39] aims to maintain a certain number of cognitive abilities by maintaining as much as possible the person's daily landmarks and by maintaining social links, thanks to the involvement of 120 trained volunteers. This village is made up of houses that can each accommodate 7 to 8 villagers, a restaurant, a theatre, a grocery store, which will allow patients to continue their daily life in optimal situations. It will also host a medical center which will ensure patient follow-up and will also be a place for medical and therapeutic research.

3.4 Description of the proposed solution

For our work, we decided to choose a person with Alzheimer's disease as the resident because few research has been done on this subject and it is still a current problem. Over the years, the number of cases of this disease increases significantly. This disease not only affects the life of the patient but also the life of those around him. In fact, the patient must always be followed, so there are two choices: (1) put him in a specialized institution, but they find it difficult to accept this situation and are often prone to runaways, temper tantrums and violence, (2) assign a caregiver to each patient, which is no longer possible. For our solution, we were inspired by the idea of the village « Alzheimer ». The village is made up of many houses, we hence looked for a way to make the life of the patient in the house easier and safer. For this, the point that we took into consideration is the safety of the individual and we therefore based ourselves on a single room in the house: the kitchen. In fact, the kitchen remains the place where there are the greatest number of dangers: risk of burns, intoxication, falls and injuries, etc. The most dangerous risks that we consider are: flooding, fire, gas and electrical appliances, as shown in Figure 3.1.

- *Flooding*: flooding is a hazard that in itself does not cause human damage but can cause significant property damage. This can be caused by forgetting a tap left open, an overflowing washing machine, etc.
- *Electrical appliances*: electrical appliances are now a common part of our lives. It has never been easier or faster to warm food since the creation of the microwave. They make our lives easier, but there is also a danger, and the main one is short circuits.

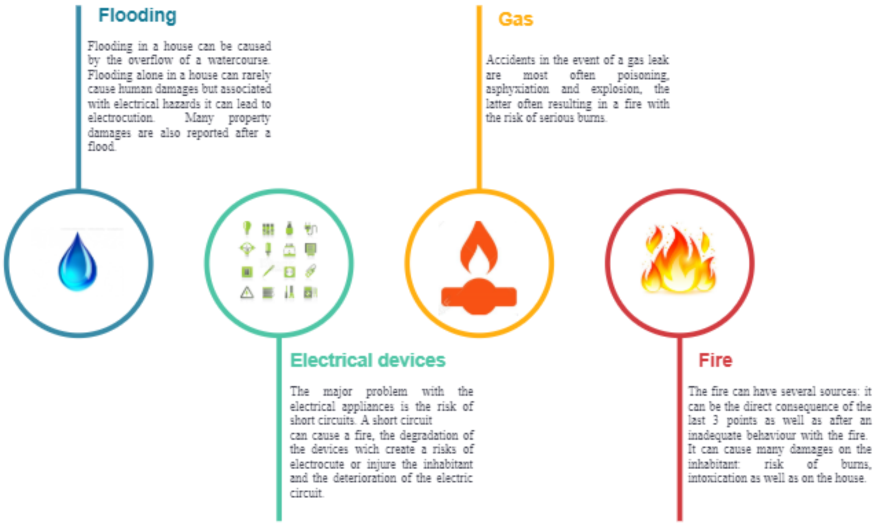

FIGURE 3.1: Representation of the four risks taken into account in our work.

A short circuit occurs when two conductors of different polarity come into contact. This contact then creates a higher current discharge, which creates a short-circuit current. Short circuits can cause several consequences from lead jumping to fire; the risks can be more or less important. They can cause irreversible damage to electrical equipment or circuits. This damages can also result in electrocution or fire. Sometimes, short circuits can cause the appearance of electric arcs [40].

If flooding and electrical appliances are still minor or rare risks, each of them in its own right, their combination however increases the danger incurred. A wet electrical appliance when turned on can create electric shock, fire, and can be a source of shock hazard aggravated by water.

- *Gas leakage*: natural gas is a safe source of energy but like any energy source, it comes with risks. Accidents in the event of a gas leak are most often poisoning, asphyxiation and explosion. The latter can be the cause of a fire if it is associated with electrical devices or the risk of fire [41].

- *Fires*: the kitchen is a suitable place for a fire to start. One out five household fires starts in the kitchen. Hobs badly switched off or defective, gas installation left unattended during cooking, tea towel catching fire or boiling oil igniting a cookbook; the origins of a kitchen fire are multiple [42].

3.4.1 Architecture of the proposition

As previously mentioned, our proposed solution to guarantee the safety of the inhabitant in the Smart Home focuses on the kitchen. The kitchen is composed of a sink, three windows, a gas cooker, a fridge, a microwave and a coffee maker, as illustrated in Figure 3.2.

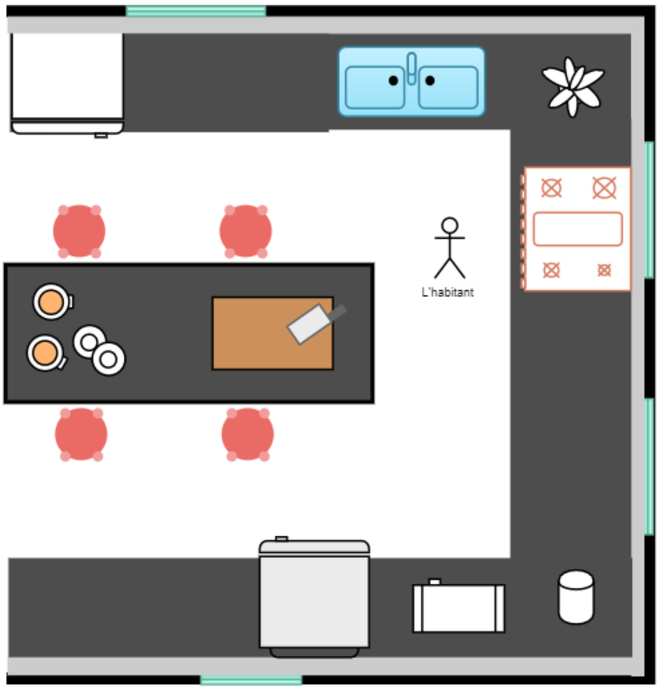

FIGURE 3.2: A representation of our smart kitchen.

The kitchen is also equipped with four types of sensors: proximity sensors that trigger when the patient enters the kitchen, temperature sensors, gas sensors and voltage sensors. The purpose of these sensors is to collect precise data that will be sent to the system as shown in Figure 3.3.

- *Proximity sensors*: a proximity sensor is a non-contact sensor that detects the presence of an object called a target. Proximity sensor simply means; a sensor that detects, captures, and relays information without any physical contact. Proximity sensors have their own characteristics: contactless sensing, unaffected by surface condition, suitability for a wide range of applications, longer service life, high speed response rate [43]. There are several types of proximity sensors, depending on how they detect a target: inductive proximity sensors, capacitive proximity sensors, capacitive ultrasonic sensors, IR proximity sensors, etc. [44].

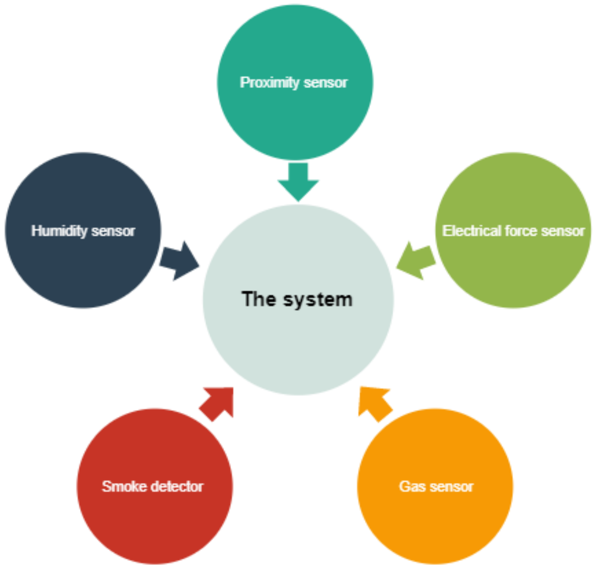

FIGURE 3.3: Interactions of sensors with the system.

For our smart home, we have chosen capacitive ultrasonic sensors shown in Figure 3.4. Capacitive ultrasonic sensors detect the presence of the target by emitting a range of high-frequency ultrasounds. It allows the detection of solid, liquid or granular objects. This sensor works as follows: the sonic transducer emits sound waves, the sonic waves bounce off the object, the wave that has bounced back is then sent to the sensor, and the time it took to send and receive sound waves is then used to determine distance/proximity [44].

The choice of this sensor is due to several reasons: first of all, it is a sensor suitable for long distance detection, its a low current consumption, this combined with the fact that it allows the detection of fluid which allows us to bypass the use of specialized sensors for the risk of flooding thus enabling cost savings. It also has many other advantages that will be indispensable: contactless detection, the fact that it is not affected by object color and transparency, it is not affected by external environmental conditions, and therefore usable in dark environments [44].

- *Gas sensor*: a gas sensor, as the name suggests, can detect gases in the monitored environment. These gases can be oxygen as well as combustible gas. The choice of sensors used will depend on a combination of factors: risk of explosion, lack or excess of oxygen, toxicity and cross-sensitivity. There are several types of gas sensors: electrochemical sensor, catalytic sensor, infrared sensor, and photo-ionic detector.

FIGURE 3.4: The four types of sensors chosen in our work.

For our work, we have chosen to use catalytic sensors, an example of this type of sensor is the ex Dräger shown in Figure 3.4. This type of sensor is most commonly used for the detection of combustible gas, which is suitable for use in a home. Catalytic sensor oxidizes combustible gases and converts the temperature change into an electrical signal. However, the main drawback of this sensor is its inability to operate in an oxygen-free environment. If the oxygen level drops too low, the gas will not effectively affect the reaction process, resulting in readings lower than the actual values on the sensor [45].

- *Temperature and humidity sensor*: temperature sensors inform a system about the temperature of a given object or place. As with any sensor, there are many types of sensors with different characteristics that make them suitable for certain environments. The DHT22 sensor (cf., Figure 3.4) is a two-in-one sensor, which makes it possible to recover the temperature of a place but also its humidity. It is capable of measuring temperatures between -40° 0 +125° with an accuracy of +/- 0.5°, and rates of relative humidity from 0 to 100% with an accuracy of +/- 2% [46]. That is why we decided to use it in our smart home.

- *Voltage sensor*: the calculation of the electrical power requires the use of current sensors. There are several types of current transducers, which differ in technology or materials used. The choice of a voltage transducer depends on: electrical requirements (e.g., desired performance), mechanical requirements (i.e., dimensions, weight, materials, etc.), and environmental constraints.

  One of the sensors that is suitable for the home and which has all the necessary features for safety uninterruptible power supplies and other battery-powered equipment for the regulation of charge and discharge current is open-loop Hall-effect current sensors (cf., Figure 3.4). These sensors have several advantages: they can measure DC (Direct Currant) currents, they provide galvanic isolation of the measuring system from the circuit to be measured, they have low power consumption, are remarkably resistant to current overloads and are relatively inexpensive [47]. This is the reason why we chose them.

3.4.2 Algorithm of the proposal

Since the Smart Home in our proposal is adapted to a patient with Alzheimer's, we started by focusing on its safety. To do this, the challenge was to identify the danger before it occurs and before there are consequences. So a prediction algorithm was put in place. Our algorithm is organized as shown in Figure 3.5. The sensors periodically capture data on their own properties and send them to the corresponding agent. For example, the gas sensor sends its data to Gas_Agent. When the agent receives the data, it process them to detect whether it is a normal or a risk data and then sends its response to the system.

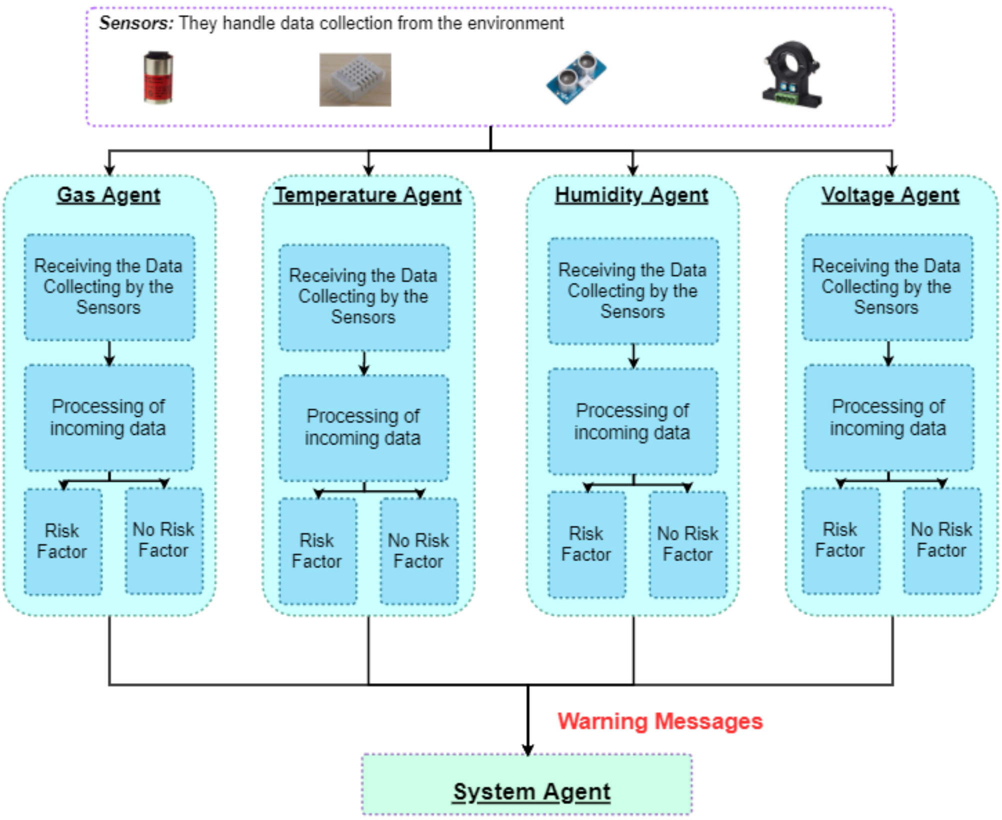

FIGURE 3.5: Representation of the proposed architecture.

The challenge is to have real-time communication between all the communicants (i.e., sensors, agents and the system) to allow the detection of danger as early as possible so that the previously established solution can be implemented.

When the agent receives the data, it first determines the patient position, if the patient is in or out the kitchen. Then, it processes and compares the received data to a dedicated value considered normal in this house. Any data above or below this range is considered abnormal or at risk. For example, if the normal temperature interval in this house lies in $[a, b]$, then any value not included in it is considered abnormal. Each agent, after determining an abnormal value, sends an alert to the system agent, which will then determine which solution to implement. This process is shown in Algorithm 1.

Algorithm 1 Structure-Agent

```
Data = 0;
alert = 0;
if (Data received from sensor) then
    Data = received data;
    if (Data < Normal Data Inf) then
        alert = −1;
        Send alert to System agent;
    else
        if (Data > Normal Data Sup) then
            alert = 1;
            Send alert to System agent;
        end if
    end if
else
    Agent sleep;
end if
```

After the agents have processed the received data and send their alerts to the system. The latter will computes them and determine the number of risks and the dangerous combination, for example, Gas-Temperature or Gas-Electrical-Humidity combination. At the end, it determines the best action to take; alert the resident or the referent, switch off a system, etc. (cf., Algorithm 2).

The actions taken depend on the alerts received, but also on the combinations of alerts, for example, if the system agent receives two alerts, one from the gas agent that says that the rate of gas is alarming and another from the temperature agent that alerts the system from a higher temperature, it will determine a combined dangerous risk, then it acts consequently by switching off the gas system and alerting a relative of the resident; his referent, as shown in Figure 3.6.

Algorithm 2 System-Agent

```
temperature = 0;
gas = 0;
humidity = 0;
electrical = 0;
if (Data received from Agents) then
    temperature = alert from Temperature-Agent;
    gas = alert from Gas-Agent;
    humidity = alert from Humidity-Agent;
    electrical = alert from Electrical-Agent;
    if (temperature & gas & humidity & electrical are not null) then
        Send an Alert to a referent and the resident, and turn off gas and electrical system (Four risks);
    else
        if (temperature & gas & electrical || gas & electrical & humidity are positive ) then
            Send an Alert to a referent and the resident, and turn off gas and electrical system (Three risks);
        else
            if (gas & temperature are positive) then
                Alert the resident and switch off the gas system.
            else
                if (humidity & electrical are positive) then
                    Alert the referent and switch off the electrical system.
                else
                    if (gas & electrical are positive) then
                        Alert the referent and switch off the gas and electrical system.
                    else
                        if (gas positive) then
                            Alert the resident and switch off the gas system.
                        else
                            if (electrical positive) then
                                Alert the resident and switch off the electrical system.
                            else
                                Alert the resident.
                            end if
                        end if
                    end if
                end if
            end if
        end if
    end if
end if
```

Since the combination of two risks is already alarming, the addition of one or two other parameters does not really change the situation, so the solution taken is practically equivalent to the one already established. In this type of case, the additional risks are still

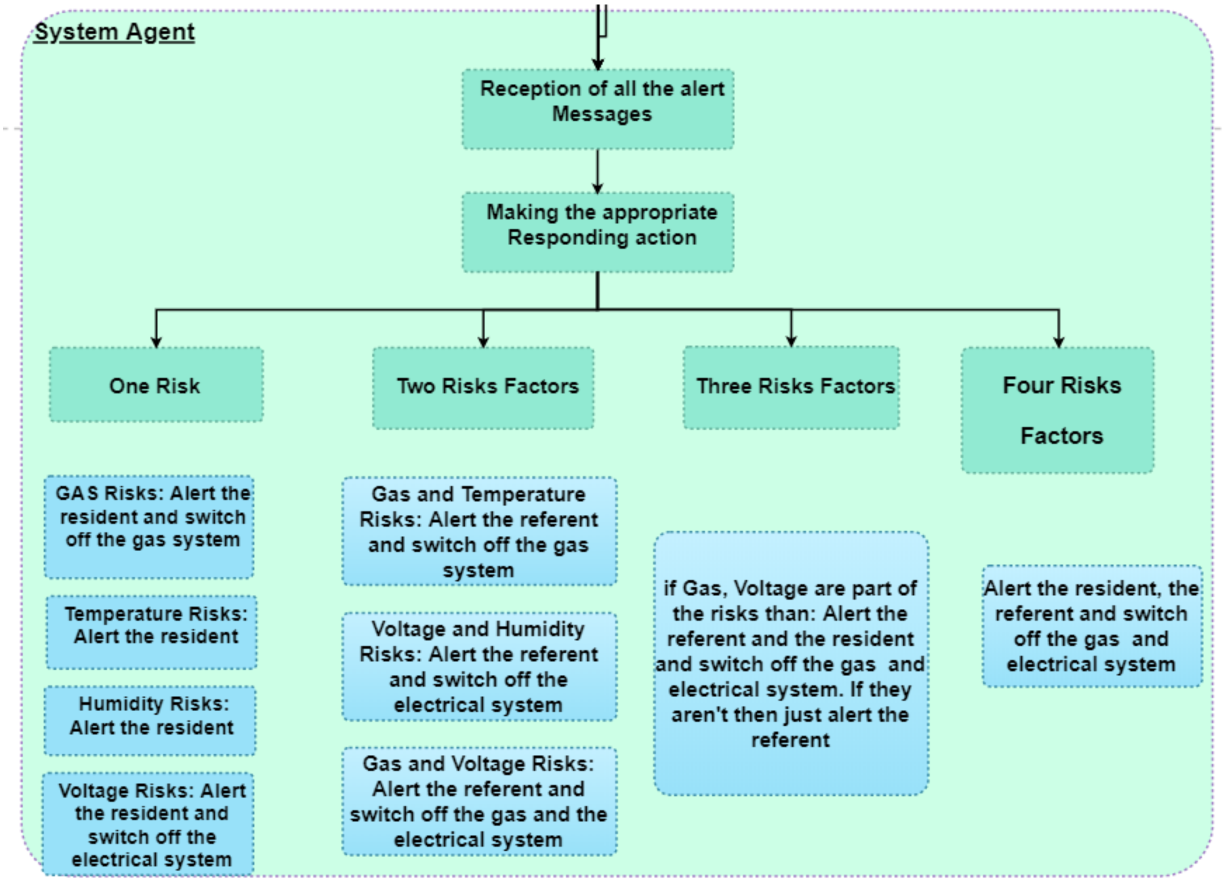

FIGURE 3.6: Representation of the possible actions of the system agent.

reported to the referent and the resident, in addition to the action taken for two risks. For example, if the voltage, temperature and humidity are reported higher than the normal, the combination of humidity and voltage is considered as dangerous because it can cause a fire, the action established for this combination is turning off the electrical system and alerting the referent. The addition of the temperature risk will not increase the danger, so the system will only notify the high temperature with the action set-ups.

3.5 Conclusion

In this chapter, we have explained how, from a simple reflection, we were able to extract our problem but also our solution: the implementation of a prediction algorithm to ensure the safety of a patient with Alzheimer's disease in a Smart Home. In the next chapter, we will explain how all this was implemented but also check its validity.

Chapter 4

Performance Evaluation

4.1 Introduction

After defining our problem and determining the solution and its architecture, we immersed ourselves in its implementation. As previously seen, we focused on a single room, the kitchen, which we considered to be the most dangerous in the house due to the many risks it faces. In this chapter, we present the environment and the conditions of our implementation and a description of the obtained results.

4.2 Simulation environment

Our solution being divided into two parts: (1) the classification of all the data collected and (2) their processing, we started to think about the most optimal way to achieve it. For the implementation of our multi-agent architecture, we turned to one of the most well-known software frameworks namely JADE (Java Agent Development Framework), while for data processing, we decided to use MATLAB.

4.2.1 JADE

As described in Chapter 3, after the system has retrieved the data from the sensors, it is responsible for transmitting them to the corresponding agent. This agent will process the data and determine the right actions to take. In order to implement our agent, we used version 4.3.3 of the JADE platform.

Java Agent Development Framework (JADE) is a multi-agent platform developed in Java in 1999 by the CSELT (Centro Studi E Laboratori Telecomunicazioni). The CSELT aims to build multi-agent systems and applications compliant with the FIPA (Foundation for Intelligent Physical Agents) Standard. JADE is a framework that consists of two basic elements: an agent platform compatible with the FIPA standard and a software package for the development of Java agents [48].

4.2.2 MATLAB

We choose the MATLAB platform for its ability to process a large amount of data in real time. It is also optimized to solve scientific and technical problems without forgetting the fact that it is a matrix-based language.

MATLAB has also the advantage of being an accessible and productive software designed for engineers and scientists. Many features are included to help them implement their work like the desktop environment designed for iterative exploration, design, and problem solving, its graphics for data visualization, as well as royalty-free deployment options for sharing MATLAB programs with end users [49].

4.3 Comunication between modules

Three main modules have been identified: the MATLAB part which will be responsible for reading the data and assigning them to the agents. The multi-agent architecture where each agent will process the data concerning its affected sensors. Finally, the agent system will check if there are any possible combined risks and be in charge of the house responses. Between each module, communication must be established as shown in Figure 4.1.

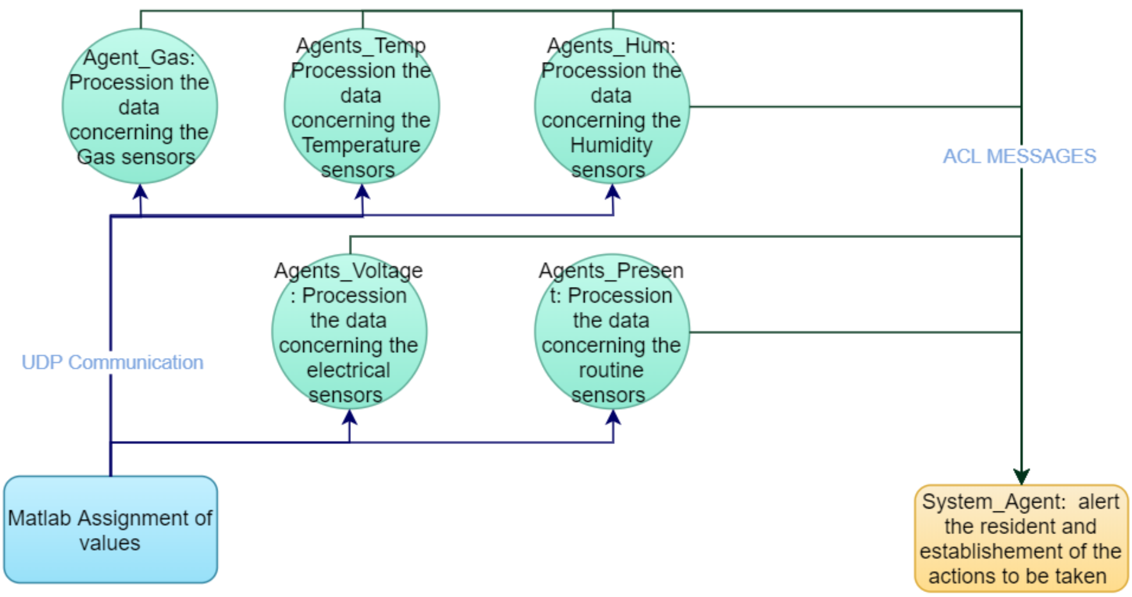

FIGURE 4.1: Interactions between the modules.

4.3.1 Communication between JADE and MATLAB

The assignment part implemented in MATLAB collects all the data from the sensors, takes care of classifying them and then transmits them to the agents who will be in charge of processing them. This architecture looks like a client-server communication, where the agent will be the server and the MATLAB part the client. As we needed real-time communication for this part of the implementation, we opted for UDP (User Datagram Packet) communication. A datagram socket is a low-level programming interface for network communication. It represents an entry point for bidirectional communication between two applications on a network. It is identified by a transport address which makes it possible to identify the processes of the application concerned. These sockets allow a connection to be established in unconnected mode, also called *datagram mode*. The data is then collected and sent in the form of packets independent of any connection [50].

4.3.2 Communication between agents

Several agents can coordinate to perform a task more optimally than a single agent, which means that communication must be established between them. For this, each JADE agent has a sort of mailbox which contains the messages sent to it by the other agents. These mailboxes are presented as a list that contains the messages in chronological order of their arrival [51]. A communication language has also to be established. For this, we had the choice between two communication languages: KQML18 (Knowledge Query and Manipulation Language) and FIPA19-ACL (Foundation for Intelligent Physical Agents - Agent Communication Language). There are no big differences between these two languages. They are almost identical in terms of the basic concepts and principles they adhere to. They differ mainly in the details of their semantic frameworks. Their differences can be a concern if they are BDI (Belief - Desire - Intention) agents, which is not our case. We have therefore turned to ACL messages for ease of use [52].

4.3.3 The dataset

In order to be able to launch and verify the proper functioning of our algorithm, we needed data that would allow us to predict any danger in our kitchen. These data that are normaly collected by sensors, have been replaced by a dataset due to a lack of equipments. There is currently no dataset available given our needs, our inhabitant and our activities. We decided thus to build our own database. To do this, we first determined the parameters to follow and for each of them the risks incurred. Each factor has a parameter dedicated to it, which determines whether it is a potential risk or not (cf., Table 4.1).

Risk	Parameter	Agent concerned
Fire	Temperature	Agent_Temp
Flooding	Humidity	Agent_Hum
Gas	R2 Gas	Agent_Gas
Electrical device	Voltage intensity	Agent_Voltage

TABLE 4.1: Different risks taken into account.

- *Temperature:* we decided to track the fire risk by a temperature parameter. For example, if the inhabitant forgot to turn off the gas cooker, as soon as the temperature exceeds the normal range, the house will issue an alert.
- *Humidity:* to check the risk of flooding, we decided to track the humidity parameter.
- *R2 Gas:* it is one of the most dangerous types of gas in a home. This may cause a risk of explosion by shock, friction, fire or other sources of ignition [53].
- *Intensity:* if the intensity of an electrical device is low, it may cause disconnection of the electrical system, but if it is too high, it may cause a fire.

We have added a last parameter that is the patient's routine. This parameter contains the hours the patient is in the kitchen. Some parameters may be affected by the latter. For example, while cooking, the temperature in the kitchen rises, which can lead to a value higher than the normal temperature and therefore trigger an alarm, which is quite normal given the situation. Hence, to avoid this kind of false warning, the patient's routine was necessary.

After determining which parameter is the most ideal for tracking our risks, we organized our own database with 508 entries for each and with a chosen duration of 1 hour, This duration was choosen based on the Dataset of electrical device where the data were collected every hour (since our dataset was a personal organized data, we had to follow the longest duration). The dataset was used to determine the normality interval of the data. We conducted some tests and statistics to find that, for example, a normal temperature in this kitchen lies in $[26.5, 28[$, but it was also used as input data (i.e., the data captured by the sensors) of our predictive algorithm.

4.4 Evaluation of performances

In this section, we evaluate the efficiency and reliability of our proposal. To do this, we have carried out simulations which allow us to recover all the elements and metrics necessary for their verification. We also present a simulation scenario and discuss the obtained results.

4.4.1 Unfolding of a scenario

The purpose of this scenario is to understand how our implementation works, but also to determine the reliability of our system. To do this, we simulate a set of 10 data and we monitor their processing. The data were chosen randomly by our system, and which we have represented in Table 4.2.

	Patient Routine	Temperature	Gas rate	Electrical intensity	Humidity rate
1	0	29.65	10.8232	118.4	55.9158
2	0	26.1991	10.2873	117.7	57.0844
3	0	25.9324	10.5279	117.4	56.6201
4	0	25.9576	8.3243	117.9	65.052
5	1	26.3553	10.9975	118.2	56.0489
6	0	25.5371	11.2946	116.2	55.4277
7	1	25.0045	11.2956	119.7	55.4006
8	0	26.15	6.0648	120.5	54.3844
9	0	26.4409	8.3735	120	54.5493
10	0	26.3241	8.3572	118.1	55.1524

TABLE 4.2: Data collection for the scenario.

4.4.2 Interpretation and meaning of the presented data

Before explaining how our system treats data, we will start by explaining the data meaning of each parameter and the relationship between all of them.

- The patient's routine consists of either a 0 or a 1, with a 0 indicating the patient is not in the kitchen and a 1 indicating the patient is in it.
- If the calculated intensity is less than 118, it may cause a disconnection, and if it is greater than 120, a risk of fire.
- Regarding humidity, the normal rate is between $[53, 61]$.
- The normal temperature in this kitchen lies in the interval $[26.5, 28[$. If the captured data is less than 26.5, it is considered dangerous and an alert will be sent, but not as dangerous if it is greater than or equal to 28.
- The normal gas level was determined in the interval $]8.8, 11]$.

Regarding the last two points, they depend a lot on the patient's routine. If the patient is in his kitchen, the interval changes a bit. The maximum temperature will drop from 28 to 29.5 and the gas rate from 11 to 12. We can then identify two types of scenarios: (1) the patient is in the kitchen, (2) the patient is outside the kitchen.

4.4.3 Identification of possible risks

At any time, the system can determine one danger, several, but also a combination which can lead to more serious consequences. For each parameter, we have two types of risks depending on its values. We represent these two risks in Table 4.2 in color: the data that were lower than normal are shown in yellow, and the one that were higher in red. This will help us understand the risks and the combination of risks.

As shown in Figure 4.1, this work is part of the implementation carried out by the agents. First of all, each agent receives the data regarding their role and they start to check whether it is normal value or risk, it also determines what kind of risk it is. In what follows, we take the sixth entry of Table 4.2 as an example.

From the patient's routine, we can see that he is not in the kitchen so we go through the second scenario. All agents treat their data in parallel and do this process. The simulation was launched in two parts:

(A) *With four agents working:* we started by launching our simulation with 4 agents; routine, temperature, voltage, and humidity, and determine the possible risks associated with each and the combination of those risks. The results of this simulation are presented in Table 4.3.

- The temperature agent receives the information that the patient is not in the kitchen and the temperature captured is equal to 25.5371. This value is less than 26.5, so it is considered a risk value. The temperature agent will then send an alarm to the agent system precising that the temperature is low.
- The voltage agent only receives the information about the electrical intensity 116.2, which is less than 118, then sends an alarm to the agent system: low electrical intensity.
- The humidity agent will do exactly the same work as the other agents. When receiving the data, it will compare it to its interval and determine that it is normal, so it will not do anything.

(B) *With the five agents* : we repeated the same simulation but with the addition of gas data. The four agents operate exactly the same as in (A), while the gas agent receives the information that the patient is not in the kitchen and the rate of gas captured is 11.2946, which is considered high in this case. It will send an alarm to the agent system: the gas rate is too high.

After processing the data and receiving the alarms by the system agent, it will first determine how many dangers have been identified and then whether their combination presents a greater danger or if they are unrelated. In our case, the three of them are not related, a low temperature will not have consequences on the electrical intensity or the gas rate, and the same for the other two parameters. In this case, the system will inform the inhabitant of these three distinct risks.

4.4.4 Results evaluation

After simulating this scenario, we evaluate the results obtained. For that, we compared them to the results that were expected in the beginning and we noted them in Table 4.3 to have a better visibility.

	One danger	Two dangers	Three dangers	Four dangers
Expected results for (A)	16	0	0	/
Obtained results for (A)	16	0	0	/
Expected results for (B)	17	0	0	1
Obtained results for (B)	17	0	0	1

TABLE 4.3: Results comparative table.

From Table 4.3, we can see that our system was able to identify and report 100% of the risks. This proves the reliability of our proposal for determining the risks and the right combination of risks. Our evaluation of the results of (A) and (B) demonstrates the scalability of the system. As the agents work in parallel and each one is specialized in its role, we can easily add as many risks, and therefore as many agents as necessary, without risking its reliability.

4.4.5 Efficiency of our proposal

After checking the reliability of our system and making sure that all risks have been recorded and alerted, we have determined the effectiveness of our system. To do this, we calculated the false alarm rate. We choose it because this type of alert can cause unnecessary panic and use of resources. The repetition of false alarms also has a consequence on the inhabitant, if too many false alarms occur it will affect the inhabitant's perception of our alerts, and will push him to ignore them knowing that each time they could be false.

To determine this factor, we have simulated our program over 10 days of data, i.e., 240 data sets. In the end, we compared the number of all notified risks with the number of actual risks. The recorded difference has been introduced into the plots of Figure 4.2. We can see that there is a slight difference between the two results. Indeed, the system has recorded and alerted the inhabitant more than necessary. From this simulation and this result, we were able to determine the false alarm rate, which is of 2%. Despite the existence of false alarms, they remain quite rare and therefore negligible, and do not affect the efficiency of our system.

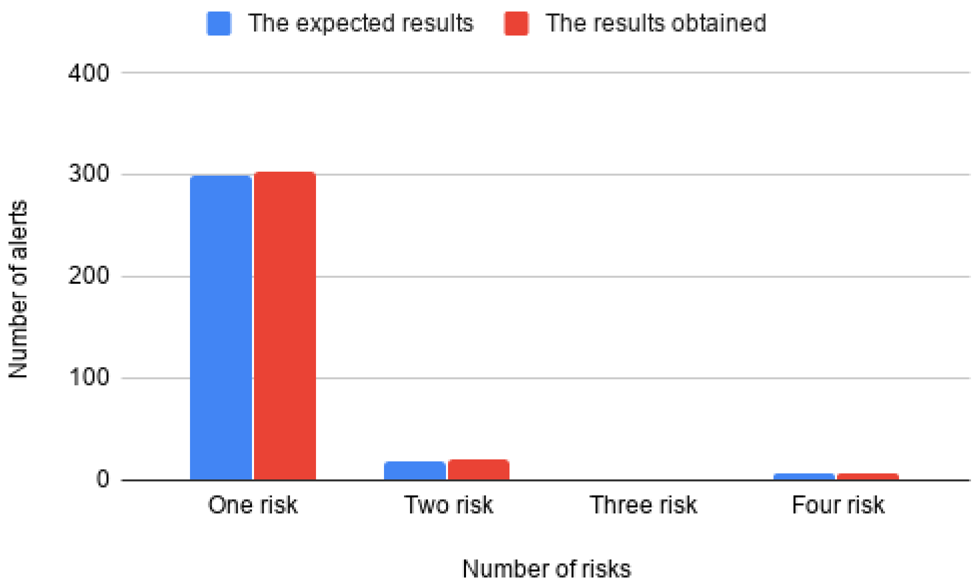

FIGURE 4.2: Comparison between the obtained and the expected results.

As shown in Figure 4.2, our system reported few combined risks, beyond the fact that several dangers can appear simultaneously, before any alert, treatment is carried out to determine whether their combinations require a specific reaction or not. For example, if both the temperature and the gas are higher than normal, this is considered a combined risk since a greater danger can occur, but if one of the two is lower, the system reports them as two different risks. This explains why the system reports such a large number of alerts given the amount of data. The system triggers so few dangerous alerts compared to the number of individual alerts to avoid worrying the inhabitant unnecessarily.

4.5 Conclusion

In this chapter, we started with a brief description of the implementation environment as well as the chosen monitoring parameters, we finally moved on to the presentation of the steps followed for the realization of our system. The aim was to demonstrate its efficiency and reliability through simulation under different scenarios and with various data sets. The obtained results meet all our expectations since the system has demonstrated its reliability, efficiency and scalability.

Conclusion and future works

Year after year, Information Technology takes another step forward in all other fields and continues to show its importance and potential. After working on Smart Homes, we can say that this is and will be a hot topic that will remain a solution to many problems but can also be a miracle for others. Whether it is to bring comfort to human beings, facilitate their daily lives or restore their independence to those who have lost it, Smart Homes offer many perspectives that are just waiting to be grasped.

We tried to add our touch to this area by working on an inhabitant too often put aside, a cognitive patient. Smart Homes can be a solution to this patient's real situation, they will be able to help Alzheimer's patients not only to work on their memory by being a treatment, but also to feel comfortable again in their own home without ignoring his security, which was the subject and purpose of our work. Our solution was divided into two parts, each with its own advantages. The multi-agent architecture guarantees the scalability of our system. No matter how many dangers are considered initially, it can always be modified and improved by adding an agent without affecting the operation and results of the system. The second part is the predictive algorithm which is at the center of all our implementations. This type of algorithm is very rarely used in security and much more used to ensure the comfort of the inhabitant, yet it makes it possible to detect a danger even before it occurs, while taking the right solutions. The existing fear at this level would be the rate of false alarms which could annoy the inhabitant or put him in danger by taking into account the solution issued, which is not the case here given the results which demonstrate its low rate.

This work having proved its effectiveness by its results, we thought of a way to improve it and bring a bonus to the life of the patient, all the ideas that we thought of are presented below as future prospects:

- Implementation of our solution throughout the house. For our work, we focused only on the kitchen, as this is the room that contains the most danger. But each room has its share of dangers and it would be interesting to adapt it;

- Substitution of the dataset with a learning algorithm that will capture and set up all the data necessary for the operation of the system: complete patient routine, temperature in the different rooms, etc.;
- Treatment of other dangers such as the risk of falling;
- Addition of a part that will allow the comfort of the inhabitant and facilitate their daily life.

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Abstract

With the increase of dependant people such as the elderly or those suffering from various illnesses, researchers are increasingly interested in the implementation of "Smart Homes" (or automated homes) to help them continue to live at home safely and independently. They incorporate common devices that control the characteristics of the house. Originally, Smart Home technology was used to control environmental systems such as lighting and heating, but recently it has been adapted to many different areas and demands, such as ensuring the comfort and safety of residents. The research in this dissertation focuses on the safety of an Alzheimer's patient in the Smart Home. Our contribution consists in adapting a predictive algorithm, which is generally used for comfort, associated with a multi-agent architecture, in order to detect dangers and consequently make the right decision at the proper time. Several simulations have been carried out which demonstrate the reliability, efficiency and scalability of the proposed solution.

Keywords: Smart Homes, Inhabitant Security, Prediction, Alzheimer Disease.

Résumé

Avec l'augmentation du nombre de personnes dites dépendantes telles que les personnes âgées ou celles atteintes de maladies diverses, les chercheurs s'intéressent de plus en plus à l'implémentation de "Smart Homes" (ou bien maisons automatisées) pour les aider à continuer à vivre chez eux en toute sécurité et indépendance. Elles intègrent des dispositifs courants qui contrôlent les caractéristiques de la maison. À l'origine, la technologie de la maison intelligente était utilisée pour contrôler les systèmes environnementaux tels que l'éclairage et le chauffage, mais récemment, celle-ci a été adaptée à de nombreux domaines, mais aussi à des demandes différentes, tels qu'assurer le confort des résidents, ainsi que leur sécurité. Les travaux de recherches menés dans ce mémoire sont axés sur la sécurité d'un patient atteint de la maladie d'Alzheimer dans la Smart Home. Notre contribution consiste à adapter un algorithme de prédiction, généralement utilisé pour le confort, associé à une architecture multi-agent, afin de détecter les dangers et par la suite pouvoir prendre la bonne décision au bon moment. Plusieurs simulations ont été réalisées qui démontrent la fiabilité, l'efficacité et l'évolutivité de la solution proposée.

Mots clés : Maison intelligente, Sécurité de l'Habitant, Prédiction, Maladie d'Alzheimer.