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Building a person home behavior model based on data from smart house sensors 2015

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Preface

When this topic was presented to me for the first time, I was really excited about the idea.

The idea of “building” a system in order to help people who live by themselves, to help track their daily activities and behaviors, and detecting when something is different from the routine and send a warning to the authorities or family member nearby. The concept of the study sounded overall really great.

At the beginning of the study, I didn’t know much about the issues in Norway regarding this problem; a lot of elderly people living alone, without anyone; but I automatically “saw” that reality in Portugal, where I’m from. Almost every week, unfortunately, it is possible to read in the news about someone who was found dead in his or her own house and was dead for some days until someone found out. To have a system like this one in a house, where someone lives alone, and if there is a problem and the system send a warning to the authorities and it is possible to save that person, it is already paid off.

Is not a complicate system, and the user does not need to be an expert in order to know how to use it, because the system will learn by itself the daily routines of the inhabitant, and will record everything through cameras and sensors and will work independently from the inhabitant.

This system is not only specific to elderly people, also can be use in a house where a young person lives, because when someone is living alone, doesn’t matter if you are young or old, if you have a problem, if you are not feeling ok, you are going to feel helpless no matter how old you are.

After the “emotional” connection with the topic, I immediately knew it would take a lot of hours with research, trying to find what was already in the market, and what other investigators had about this topic, trying to find some gap about the topic and complementary it.

One thing that worried me was definitely the programming part. But I tried to have an open mind related with that and thought it would not be a problem.

Key words: Sensors

Smart house

Store information

Activities

Behavior

Cameras

ID3 algorithm

Fuzzy Logic

Neural Networks

Neural-Fuzzy

Markov Chain Monte Carlo

Communication Protocols

Database

Text Files

CSV Files

Resumo

O propósito deste trabalho é construir um modelo baseado em informação captada por sensores e câmaras em uma casa onde viva somente uma pessoa.

A primeira parte do trabalho consistiu em reunir informação que ajuda-se a perceber o que já tinha sido feito neste âmbito por outros engenheiros. Na realização deste trabalho, a parte que se revelou mais acessível foi a que envolveu a procura de informação sobre os diferentes métodos a usar no sistema, tais como Lógica Fuzzy, Redes Neuronais ou o método Monte Carlo via Cadeias de Markov.

Em contrapartida, investigar as diferentes maneiras de guardar a informação provou ser mais desafiante.

Foi praticamente impossível encontrar informação sobre os métodos usados para guardar informação recolhida pelos sensores e câmaras. A maior parte das vezes, os engenheiros não mencionavam a parte da informação relativa a este aspecto, simplesmente apresentavam os seus resultados e as suas conclusões. Além disso, quando o uso de informação era mencionada, a mesma relacionava-se com informação online, ou só informação já recolhida por sensores e câmaras, sem quaisquer detalhes. Era espectável encontrar mais informação sobre os métodos de guardar informação, mais específica, como a informação recolhida era ligada entre si e como o sistema iria interpretá-la e que resposta iria dar.

Devido à falta de informação sobre como armazenar a informação recolhida, ficou decidido que se teria de assumir uma maneira para o fazer e com isso construir o modelo. Este modelo será referido neste documento. Devido a problemas relacionados com a parte da programação e com a falta de tempo, foi impossível construir o modelo usando os, considerados, melhores métodos.

Não obstante, foi possível decidir as melhores opções para construir o modelo, assim como algumas formas de o fazer. Foi decidido a maneira como armazenar informação, o protocolo de informação a usar e o método que irá inferir com as actividades e comportamentos do habitante.

Abstract

The purpose of this work has been to build a model based on data collected from sensors and cameras in a house with only one inhabitant.

The first part of the work consisted of gathering research in order to try to understand what was already made by other engineers. One part stood out to be less complicated, as it evolved around finding information about the different methods to use with a system like Fuzzy Logic, Neural Network or Markov Chain Monte Carlo.

However, investigating different ways to store information proved to be more challenging.

It was pretty much impossible to get some information about the way people store the information collected from sensors and cameras. Most of the time, other engineers never mention the part related with the data, but simply presented the results and then their conclusion. Moreover, when the use of data was mentioned, it was simply related to online data, or just data which was stored after being collected from sensors and cameras, without any further detail. It was expected to find more information about the way the data was used, more specific information, covering how all the information was connected to each other, and how the system would interpret all the data and the responses.

Since the lack of information related with the data, it was decided to assume a way to store the information and with that, a model was built. This model will be referred to within this paper. Due to problems with programming and lack of time, it was impossible to build a model by using the best methods. Notwithstanding, it was possible to decide all the best options to use to build the model, along with some ways to do it. It was decided the way to store information, the Communication Protocol to use and the method to infer with the inhabitant activities and behaviors.

Acknowledgements

First of all I would like to say a big big thank you to my all-time best friends, my parents, Carlos Mendes and Angélica Rosário, for always supporting me, always being next to me, and allowed and helped me to move to Norway in order to finish my Master; a big thank you and I am forever thankful.

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Abbreviations

Abbreviations	Explanation	Abbreviations	Explanation
ID3	Iterative Dichotomiser 3	**SQL**	Structured Query Language
RGB	Red Green Blue	**Mat File**	MatLab File
NTC	Negative Temperature Coefficient	**CSV**	Comma Separated Values
PTC	Positive Temperature Coefficien	**ASCII**	American Standard Code for Information Interchange
CCD	Charge Coupled Device	**MFs**	Membership Functions
EIB	European Installation Bus	**FOU**	Footprint of Uncertainty
TCP	Transmission Control Protocol	**UMF**	Upper Membership Function
IP	Internet Protocol	**LMF**	Lower Membership Function
OSI	Open Systems Interconnection	**GIS**	Geographical Information System
ISO	International Standards Organization	**IMP**	Mexican Petroleum Institute (Instituto Mexicano de Peroleo)
FTP	File Transfer Protocol	**BUS**	Binary Unit System
Fast-TP	Fast Transmission Protocol	**SDK**	Software Development Kit
HTTP	Hypertext Transfer Protocol	**TDNN**	Time Delay Neural Network

Abbreviations	Explanation	Abbreviations	Explanation
HTML	HyperText Markup Language	**MCMC**	Markov Chain Monte Carlo
IT	Information Technology	**HC-HMM**	Hierarchical Context Hidden Markov Model
IRC	Internet Relay Chat	**SCR**	Spatial Context Reasoning
BR	Behavior Reasoning	**d-HCMCP**	Discrete Markov Chain Monte Carlo with People
TCR	Temporal Context Reasoning	**MCMCP**	Markov Chain Monte Carlo with People

Chapter 1

Introduction

In this chapter is made an introduction of the problem of living alone.

It is also described the way how the text is organized and the notion used in this work.

1 Introduction

1.1 Framework

As an unfortunate result of the evolution of modern society, elderly people are in a higher degree than ever left to themselves once they reach retirement age.

In order to protect and help these individuals, experts has developed an automation system that works with computer systems to help those who live alone.

The process start by installing cameras and sensors around the house, which will connect to a computer with internet access; it is not a complex system and it works without the intervention of people, and do not need any special knowledge on the part of the house person where the system is installed.

The system studies the daily habits of those who live in the house; hours of waking up, going to the bathroom, going to the kitchen, going to the room to get dressed, sitting on the sofa in the living room watching TV, time to eat. All these little habits are picked up by sensors and cameras, stored and learned by the system; what if ever the system detects that the inhabitant is lying on the kitchen floor, or get up at dawn and go to the balcony, are not normal habits of the person and automatically warns local authorities or a family member that is closest, because may have been something serious with the person.

Although this is a system more for elderly people, because there is an assumption that mostly elderly people live alone and need more help from others, it is not a system only focusing on these types of people, as younger people also can use it, as far as they live alone.

The system will not perturb the life of the inhabitant, by the contrary, will only help to keep the inhabitant safe, in case some accident occur. And since the system will constantly learn the daily habits, it will start to help him or her with normal routines in the house; it knows the inhabitant will arrive at the house at specific time of the day, so when he opens the door, the light in the entrance is already on. It knows he or she leaves the house at specific times, so in case the person forgets to turn off some light, the system will do it. It knows the person likes a certain temperature in the house, so automatically, it turns on the air conditioning for that temperature.

1.2 Document structure

The thesis is organized in 7 distinctive chapters.

In the chapter 1 is made an introduction of the modern society problem, elderly people are left alone. There is also a brief presentation of the solution in order to help who live alone.

In the chapter 2 there is an explanation how the system works, the use of various sensors to collect as much information possible, to store information collected and a reference of the methods used to infer a person activities and behaviors.

In the chapter 3 there is the explanation between activities and behaviors. There is also presented the ID3 algorithm in order to create the system to be used in the house. It is also explained the different methods used.

In the chapter 4, based in the previous chapters, it is a selection of goods methods to use in the house to have a good system, with good response when something wrong happens.

In the chapter 5 there is the simulation using the selected methods in chapter 4.

In the chapter 6 it is a discussion about the different methods used, with the advice for future studies in this field, in order to facilitate the work of future investigators.

The conclusion in the last chapter, referencing the problems with the simulation part and not be able to take the best lessons from it.

Chapter 2

Ways to represent and store information

In this chapter it is presented the various types of sensors and the different Communication Protocols.

It is also presented the aspect how the information is treated.

2 Ways to represent and store information

The system to implement in the house consists in a computer with internet connection, sensors and cameras.

Movement sensors to help to locate the inhabitant in the house (chapter 2.1.1); temperature sensors that will “detect” the ambient temperature and when is lower or higher than the one define for the inhabitant will turn on or off the air-conditioner (chapter 2.1.2); water sensors to help the inhabitant when he or she forgets to close a tap (chapter 2.1.3); sensors in every doors and windows for the system to know when they are open or close (chapter 2.1.4) and cameras which are a complement to the movement sensors (chapter 2.1.5).

The movement sensors help to understand in which division the inhabitant is and the cameras help to “see” what the inhabitant is doing (e.g. if he or she is just walking in the kitchen, if he or she is standing, laying down on the floor).

In order to collect the information and for the system to process it and learn the daily habits of the inhabitant, the house has to have sensors and cameras, not a lot, but enough to catch every movement of the inhabitant.

Movement sensors will transmit to the system in which division of the house the person is.

Temperature sensors will give the system the normal temperature of the house, which the inhabitant feels comfortable with.

Water sensors will help to remember the inhabitant when he forgets to turn off the tap and can also have the function to control how much water is used every month, in order to help to reduce the water bills.

Sensors in the doors and windows will help to remind when a door or a window is open or unlocked. The system will give the inhabitant the sensation of comfort, safety and transmit to the system when some stranger tries to enter the house. It will also give the

information to the system if the inhabitant opens a door or window at a time he or she wasn't supposed to do so.

The use of cameras will make facial recognition of the inhabitant (if there's more than one person in the house), they will work together with the movement sensors to see if the inhabitant is sitting in the kitchen, in the sofa, in the bed, standing, lying in the bed, in the sofa, lying in the floor if something is wrong.

All the sensors and actuators will be connected to the computer, which will have special software to "translate" all the inhabitant's movements in the house to an understandable reading used by the authorities and family members.

The information collected by the sensors and cameras must be stored (chapter 2.1.7) in order to be use by the chosen method (chapter 3).

If the method to be used is the Fuzzy Logic, Neural Network or Neural-Fuzzy, is important to have stored information to use as inputs. With Fuzzy Logic is also important to store the rules to use.

If the method to choose is the Markov Chain Monte Carlo, is important for the system to know what happened exactly the moment before, in order to know what will occur in the next movement.

For the system to know how to react is important to have information stored to compare, to understand if the inhabitant's behavior is normal or if something is wrong.

2.1 Type of sensors

2.1.1 Movement sensors

Ultrasonic Sensors are one type of movement sensors that can be used in this kind of systems. Like Marcelo Mazzaroppi[1] refers to in his paper, the Ultrasonic Sensors generate ultrasonic waves from the movement of a surface, which movement creates compression and expansion of the environment.

The sound waves generated by the ultrasonic sensors are transmitted in a conical shape; when the wave is intercepted by an object, as it is possible to see in figure 2.1, is reflected back to the sensor passing information about the distance of the object and the speed to the displacement sensor.

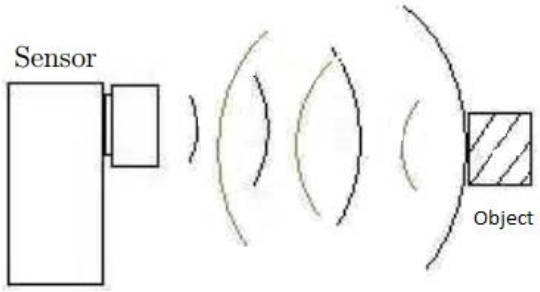

Figure 2.1 - Transmission and reflection of ultrasonic wave [1]

Ultrasonic Sensors are active sensors of presence and movement, and have the advantage of not only detect the presence of objects, but also allow the calculation of the distance and the speed which they move. Other advantages of these sensors are the ability to detect small objects over long distances and resistance to external disturbances such as vibration, infrared radiation, environmental noise, and electromagnetic radiation.

One of the most frequent configurations of the Ultrasonic Sensors is the mounting transmitter and receiver in the same package. However, the ultrasonic signals can be used to create an ultrasonic barrier. In this configuration the transmitter and receiver are positioned on opposite sides, as it possible to see in figure 2.2. The detection of the object or person will occur since the signal ultrasonic, which now engages the sender to the receiver, is stopped. For more detailed information, is advisable to read the paper[1].

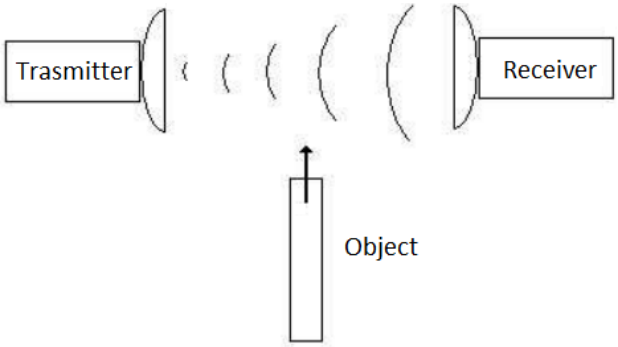

Figure 2.2 - Ultrasonic barrier conversely [1]

In the Yuri Yoshihare et. al paper[2], they used specific sensors, such as, Kinect, Sun SPOT and Wireless Optical Oscillo-sensor (figure 2.3).

The Kinect is a motion sensing input device developed by Microsoft Corporation and was used to gather environmental data and human movement. Have several functions such as 3D distance image sensor, microphones, RGB camera, accelerometer, and tilting-up mechanism. Can also measure the distance from devices like a real time camera and can be connected to a computer through usb. With the 3D measurement of color image, Kinect can also recognize human gestures and movement using OpenNI and OpenCV. The measured data are transmitted to the database server, and extracted for further processing.

The Sun SPOT (Sun Small Programmable Object Technology) is a wireless sensor network (WSN) developed by Oracle Corporation (Sun Microsystems). The device is built upon the IEEE 802.15.4 standard. Sun SPOT is small, wireless, battery-powered device developed at Sun Labs. This device can be used in a wide range of applications including robotics, environmental monitoring, asset tracking, proactive health care and many others. Sun SPOT is powered by a specially designed small-footprint Java virtual machine, called Squawk that can host multiple applications concurrently, which requires no underlying operating system.

A wireless optical oscillo-sensor (developed by NEW SENSOR Incorporated) is used for estimating human states on a bed. The sensor composed of pneumatic sensor and ultrasonic sensor. Here, human state is classified into “sleep”, “rollover”, “cough”, and “none”. Is advisable to read the paper for more detail information and to know how the sensors were used by Yuri Yoshihare et. al[2].

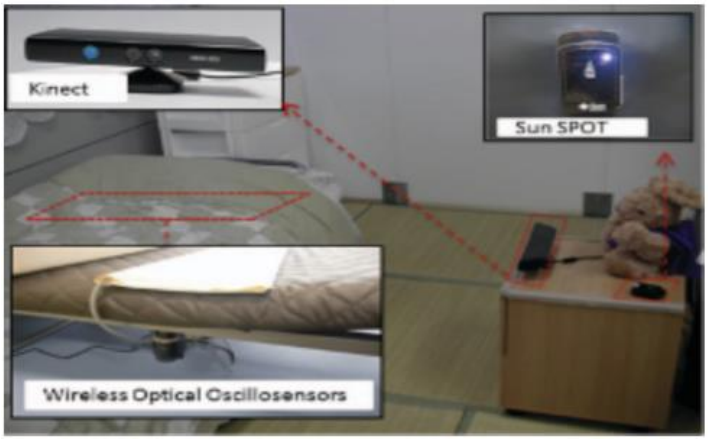

Figure 2.3 - Devices inside the room [2]

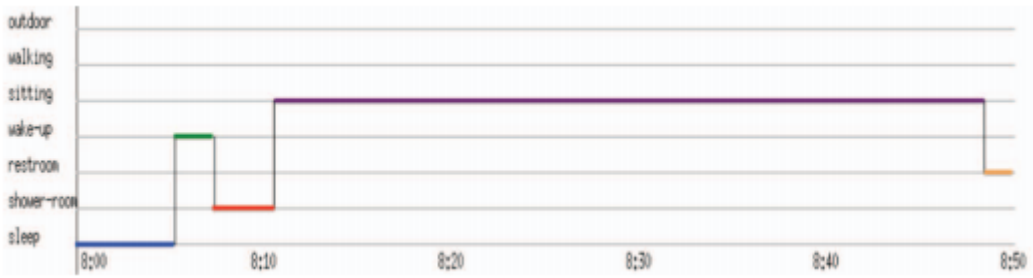

Figure 2.4 - Visualization of human behavior inside the room [2]

The wireless optical oscillo-sensor presented in the Yuri Yoshihare et. al paper[2] is perfect to use in the bed and in the sofa, where is also possible for the inhabitant to lay down. The sensor can transmit to the system when for example the inhabitant sits in the sofa, but after a while decides to lay down, to watch some TV, or even to take a nap.

The Kinect presented in the same paper[2], is also a must have to put in every division in the house (figure 2.4). The cameras will help, for example, to do the facial recognition if there is another person in the house, but if there is only one person, the Kinect system will help to track every movement of the inhabitant.

The Ultrasonic Sensors presented in Marcelo Mazzaroppi[1] paper, are really useful to have in every door of the house, because it will transmit to the system when the inhabitant goes from a division of the house to another, also helps the system to understand how long the person stays in each division, according with the time of the day, can represent different behaviors; be in the kitchen at 7 in the morning, is different from being in the kitchen at 8 in the night, which represent having breakfast and having dinner, respectively.

2.1.2 Temperature sensors

Temperature sensors are the element that will "feel" the temperature and pass this information to the reading circuit and like Gustavo Rodrigues de Souza[3] explained on his paper, exists two different types of thermistors, NTC and PTC (figure 2.5).

Both are thermally sensitive resistors, are electronic semiconductor and the electrical resistance varies with temperature, but the NTC is more used compare with the PTC.

The NTC is more easily to be manufactured, are more sensitive to temperature variations, sensitive to small variations in temperature and they can work between -50ºC and 150ºC.

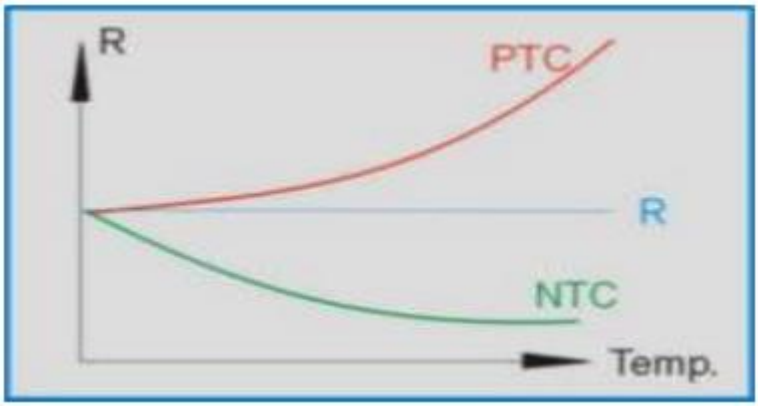

Figure 2.5 - PTC and NTC curve sensors [3]

The temperature sensors can be placed in specific places around the house and constantly will read the ambient temperature to check if is the temperature appropriate to the inhabitant and will activate the air conditioning to give hot air or cold air, depending with the readings by the sensors.

2.1.3 Water sensors

According to Jon Froehlich et. al[4], water is essential to many home activities such as washing, cleaning, cooking, drinking, gardening which are in turn central to important potential ubiquitous computing applications, helping elders live more independently, helping people monitor their own water usage to reduce waste.

Jon Froehlich et. al[4] focus on the HydroSense system, which is a low-cost and single-point solution for activity sensing mediated by a home's existing water infrastructure. This is based on continuous analysis of pressure within a home's water infrastructure. The HydroSense identify individual water fixtures, like toilet, a kitchen sink or a shower according to the unique pressure waves that propagate to the sensor when valves are opened or closed; is also possible to estimate the amount of water being used.

The system can be easily installed at any accessible location within a home's existing water infrastructure. Typical installations will be at an exterior hose bib, utility sink spigot, or water heater drain valve (figure 2.6). If unavailable or not easily accessed, like an apartment, HydroSense can also be installed at the water connection point for a dishwasher, clothes washer, or toilet. All of these are simple screw-on installation points, with no need for a plumber. For more information about the way the sensor works, is advisable to read the paper[4].

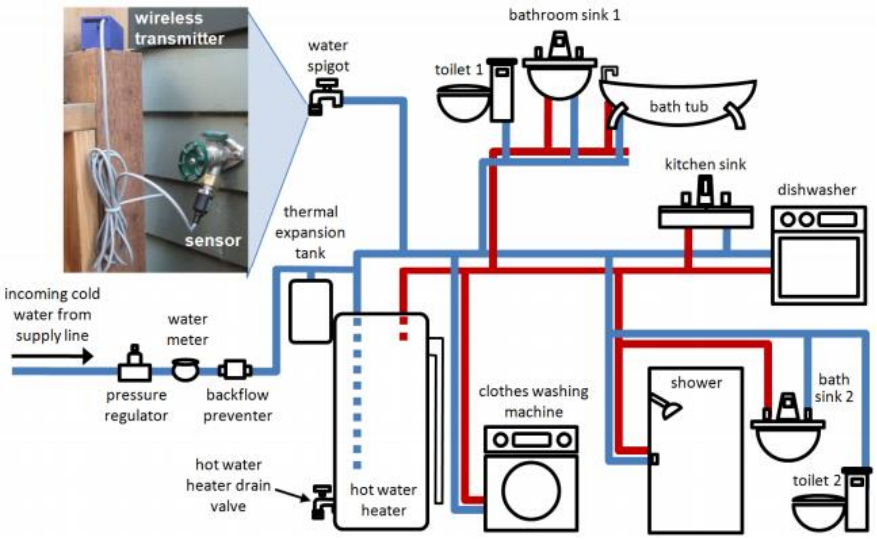

Figure 2.6 - An illustrative schematic of a basic plumbing layout in a two-bathroom home [4]

The system presented in Jon Froehlich et. al paper[4] is not also good to constantly checking if a tap was open, for example, after doing the dishes or after taking a shower, but also to control the amount of water used by the inhabitant and help to reduce the water bills.

2.1.4 Door and window sensors

Regarding door and window sensors, the option can be the Z-Wave Door & Window Sensor from AEOTEC[5]. If some door or window is open or closed the system will get a warning about what specific door or window was open or closed.

The system can be programmed and perhaps an open door means that the lights should turn on and welcome someone home or perhaps an open window means that an alarm should be trigged.

The Door & Window Sensor is completely wireless and despite its small size, it's powerfully. It uses a special Z-Wave wireless signal that aims to cause no interference with other technologies in the house. That same wireless signal is ultra-low power, helping the battery last for years. Uses as little power as possible, with an average of 2 years passing before needed to change its batteries.

This type of sensors can give the feeling of safety to the inhabitant in case if he or she forgot to close the entrance door or a window, for example. The system may issue a warning to remember to close it; but at the same time, it can be used as a safety measure if someone from outside is trying to get in using a window, or if the entrance door is being opening from outside in an hour that supposed to be closed.

2.1.5 Cameras

The type of cameras to be used can be CCD (Charge Coupled Device) cameras and according to Spectral Instruments Inc.[6], the function of a CCD can be visualized as an array of pixels collecting photons. Each pixel in the array is exposed for the same amount of time to the photons. The pixels fill up with a varying amount of photons, and the CCD is then reading one array at a time. This process is initiated by pouring photons into the adjacent empty column. The arrays in this column transfer their photon down to a final pixel where the electronics of the camera read-out this pixel (the computer measuring the array) and turn it into a number that can be understood and stored by a computer.

There is also the possibility of using web cameras, normally used in a computer, cheaper when compared with the CCD cameras, but not with the same quality of the CCD.

The use of cameras in the house is with the purpose of doing the facial recognition of the inhabitant in case he or she is not alone at home and give the information to the system who is doing what.

2.1.6 Communication protocols

In an automation system home where sensors and actuators exist, is essential to have a language to allow all the elements to communicate with each other, that language is called communication protocols.

As Vitor Lins and Waldson Moura[7] referred on their paper where they give example of three different communication protocols, X10 (the oldest and used worldwide), EIB and LonWorks.

The X10 protocol is the oldest protocol used in home automation applications; its purpose when created was to transmit data by low voltage at very low speed and very low cost. When using residence's electrical lines is not necessary to have new cables connect the devices.

Since the X10 protocol had its patent expired, any manufacturer can produce X10 devices and offer to the public without payment of fees related to patents.

The X10 is in the market more than 30 years and with the implemented technology, X10 products have a very competitive price and the installation is carried out by electricians without knowledge of automation or computer or even by users.

According to Vitor Lins and Waldson Moura[7], the EIB protocol (European Installation Bus) was developed by some European companies in electrical equipment market with the goal of creating a system that create a barrier to imports of similar products and systems that were and are being produced in Japanese markets and the United States where those technologies have a higher level of maturity compare with the ones produced in Europe.

The goal was to create a European standard that enables communication between all devices on a facility, a home or office building. The EIB has a decentralized architecture. It defines a relationship element - to – element between devices, allowing the intelligence distribution between sensors and actuators installed.

The EIB transmits data through telephone cable, ethernet networks, radio frequency signal and infrared.

The last protocol that Vitor Lins and Waldson Moura[7] referred in their paper is the LonWorks protocol. Was introduced by Echelon Corporation in the year 1992 and since then multiple companies have been using to implement distributed and automated control networks.

Despite being designed to cover all the requirements of most control applications, has only been successful its implementation in administrative buildings, hotels and industries. Due to their cost, the LonWorks devices have not had large deployment in homes, mainly because there are other technologies with the same features and much cheaper.

The success that LonWorks has been in professional applications in which matters a lot more reliability and robustness that the price itself, should be from the beginning offer solution with decentralized, end to end architecture allowing the intelligence distribution between sensors and actuators installed and covering from the physical level to the application level most control networks projects.

As Microsoft explained in their website[8], TCP / IP (Transmission Control Protocol / Internet Protocol) is based on a four-layer reference model. All protocols belonging to the TCP / IP protocol suite are located in the top three layers of this model.

Each layer of the TCP / IP model corresponds to one or more layers of the reference seven layers models of the Open Systems Interconnection (OSI), proposed by the International Standards Organization (ISO), (figure 2.7).

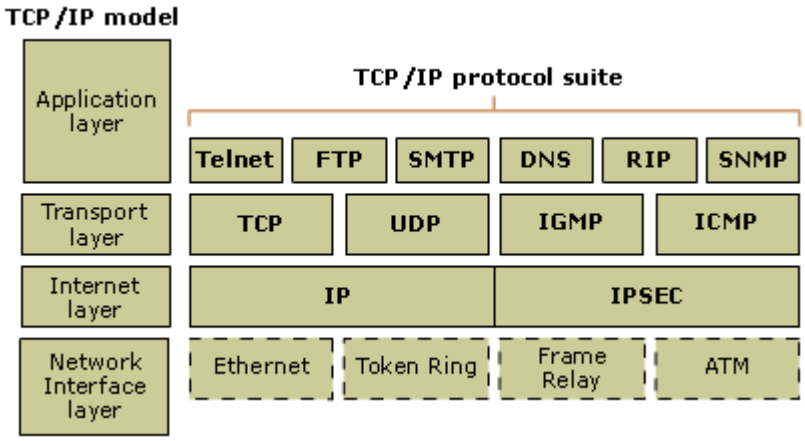

Figure 2.7 - TCP / IP model with TCP / IP Protocol Suite [8]

The application layer defines the TCP / IP application protocols and how host programs establish an interface with transport layer services to use the network.

The transport layer provides session communication management between host computers. Defines the service level and the connection status of used while date transporting.

The internet layer packs data into IP datagrams, which contain the source and destination address information used to route datagrams between hosts and networks. Run the IP routing datagram.

The network interface layer specifies the details how the data is physically sent through the network, including how bits are electrically signaled by hardware devices that interface with the network, such as coaxial cable, optical fiber or twisted pair copper wire.

As Faculdade de Engenharia de Universidade do Porto[9] (University in Porto, Portugal) explained in their document about TCP / IP, represents a set of protocols which enable the communication between all the equipment that constitute the network. It is a protocol structured in layers where each layer uses and provides services to the adjacent layers. Each layer only deals with information that matches their function.

TCP is a protocol for reliable layer transport where is guarantee the data is fully transmitted to the correct target hosts using the sequence which they were sent. TCP segments the information from the Application Layer into small information blocks (datagrams) by inserting them a header so that it is possible the data reassembly in the destination host. This header contains a set of bits (checksum) that allows both the validation data and the header itself. Using the checksum allows the target host to retrieve information in case of simple errors with transmission (where the network corrupts the package). Whenever the information is impossible to recover or TCP / IP package is lost during transmission, it is the TCP task to re-transmit the package. For guarantee porpoise, is necessary the target host to send a message "acknowledgment" to the source host, meaning there were any errors during the transmission.

The TCP protocol is divided in some characteristics:

- Data transfer: transmitting point-to-point data blocks in full-duplex mode
- Data transfer with different priorities: first transmits datagrams containing higher priority signaling
- Establishment and release of connections
- Sequencing: sorting of the received packets
- Segmentation and reassembly: TCP splits the data to be transmitted into small blocks of data, identifying them so that in the target host is possible to reassemble them
- Flow control: TCP is able to align the transmission of datagrams to the transmission conditions (e.g. speed, traffic) between the various systems involved.
- Error control: the use of checksum checks the transmitted data is free of errors. It is possible, in addition to their correction detection.
- IP multiplexing: since the concept of ports is used, is possible to send data from different types of services (different ports) to the same destination host.

The IP protocol defines the shipping mechanisms of datagrams. Is a protocol not oriented to the connection, where each IP package is treated as an independent unit of information and does not have any relationship with any other. In this datagram are placed relevant information for sending the package to the destination.

The IP protocol is responsible for communication between hosts on TCP / IP. Is responsible for the communication between each network element to allow the transmission of a message from a source host to a destination host, the datagram can go through multiple subnets (the source and destination hosts are identified by IP addresses). The IP protocol is unreliable, which is a responsibility of higher layer protocols, including TCP. Thus, no mechanism is used for flow control or error control data, only by checking through a header integrity checksum to ensure that the correct gateway to forward datagrams.

The most important functions performed by the IP protocol are the placement of an independent addressing scheme of the used network and independent from its own network topology, in addition to the ability to route and make routing decisions for the messages transport between the elements that interconnect networks.

The IP protocol is divided in some characteristics:

- Unreliable datagram service
- Hierarchical addressing
- Ease of fragmentation and reassembly of packets
- Special field indicating which transport protocol to be used at the top level
- Identification of the datagram importance and the required level of reliability to offer priority in transmission
- Disposal and lifetime control of the packages which travel on the network

TCP receives messages from the Application Layer, divides them into fixed-size datagrams and inserting them a header and then send them to the IP layer. These data are not handled by the IP layer, the main IP function is to find a way to the datagram reaches the end of the link. For the intermediate systems in the network to relay the datagram, a header in the IP package is added, which mainly consists of a source IP address, destination of the datagram and a number that corresponds to the protocol used in the Transport Layer. The IP packages as they pass through sub networks are fragmented into smaller units.

When IP packages arrive at their destination, they are reassembled (when they passed by sub networks needed to be fragmented) and sent to the TCP Layer which is responsible for verifying data integrity. If the checksum of the package does not match the expected value and not be able to retrieve the package, this is discarded and a message is sent to the source host to ask to re-send the package. It should be noted that TCP and IP have separate checksums for efficiency and safety.

Krishnan Lage Pontes et. al[10] documented in their paper the FTP and also implemented the Fast-TP (Fast Transmission Protocol) and did the comparison between both Protocols. Was explained that a FTP communication is normally consists by a connection phase, where the client receives authorization, follows by an operational phase where files are transferred and commands are passed from client to server while the connection last. As was explained, normally there's a human as final user as a client and the connection duration is irrelevant; but there are times the final user is an application and its operational requirement comes down to one or two transmission file from or to the server. In this type of environment the time spent with the connection process becomes extremely relevant.

FTP uses the Telnet Protocol on the connection control and Krishnan Lage Pontes et. al[10] implemented in their paper, a method to avoid the use of Telnet in order to save a significant amount time. The Telnet connection is actually long because is where the authentication and login are done with the operating system.

The Fast-TP uses sockets and runs over TCP Protocol. A socket is basically an IP address associated with a port; after choosing the port where the client is going to connect to the server, the server will work by "listening" that port and then establishes a connection with the client socket in another port, while the duration of the communication or output for time-out.

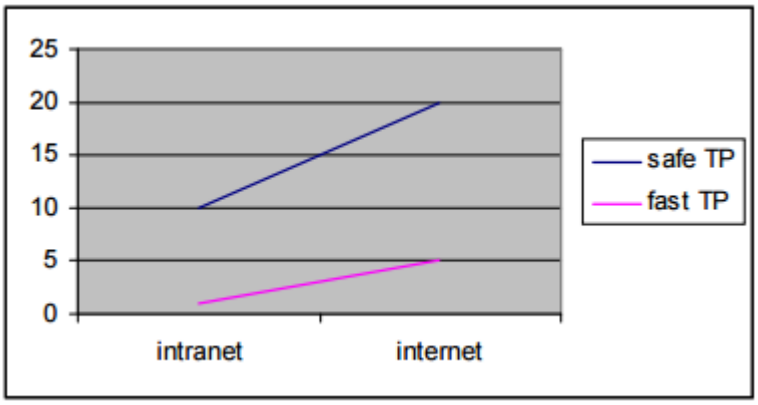

Figure 2.8 - Results. Time was in seconds [10]

By avoiding the Telnet Protocol, is possible to see there is a huge reduction in the time, when is transferring data in the intranet and in the internet, (figure 2.8).

They concluded as a successful using the Fast-TP instead of the conventional one, since the transferring time was reduced. Was also mentioned the safety aspects, confidentiality and authentication were achieved with each user having a pair of public and private keys. Integrity was guaranteed by a Hash Function.

As is possible to see in the Santa Catarina University (Brazil) website[11], in the Informatics and Statistics Department, was referred the use of other Protocol, the HTTP – Hypertext Transfer Protocol, which is a Protocol standardized to transfer through the network files containing hypermedia documents. In addition to the Protocol for Hypertext Transfer, HTTP is a Protocol for information access with efficiently to "jump" according with the Hypertext requirement. HTTP transfers mostly HTML documents, but is open to support an unlimited and extensible set of formats.

According to the Norwegian Health Directorate[12], want to implement in Norway, until the end of 2018, a change in the communication platform from analogic to digital.

Sweden and Norway conducted experiments to change the communication platform from analogic to digital in security alarms.

Sweden tested some installations between May 2010 and May 2013; they concluded it was really hard the digital communication in security alarms with analogic communication platform. In the report, was said the best solution is to change everything to the digital communication platform using the internet technology (IP) to communicate with each other.

The Norwegian Health Directorate[12] thinks is recommended the use of hybrid solutions (analogic and digital combined), but until the end of 2018 is expecting the changing is done in order to have just digital communication platform.

The Norwegian Health Directorate[12] recommends the use of IP as main way to communicate. Nowadays in Norway, there are several commercial communication providers which transmit the IP protocols; can be divided in two groups: fixed telephony providers broadband and mobile broadband providers.

Related with the data storage, pretends to be used an IT system, where information is stored and indexed. The information treatment based on common components ensures a good interaction and sharing information.

As it is possible to read in the Charles M. Kozierok's paper[13], at the very top of OSI Reference Model stack of layers, is possible to find the Application Layer (Layer 7) which is the one that is used by network applications (figure 2.9). For example, sending an e-mail, firing up a Web browser, or using an IRC chat program, all of these involve protocols that reside at the application layer.

The application layer is the only one that does not provide any services to the layer above it in the stack; instead, it provides services to programs that want to use the network, and to the user. So the responsibilities at this layer are simply to implement the functions that are needed by users of the network. And, of course, to issue the appropriate commands to make use of the services provided by the lower layers.

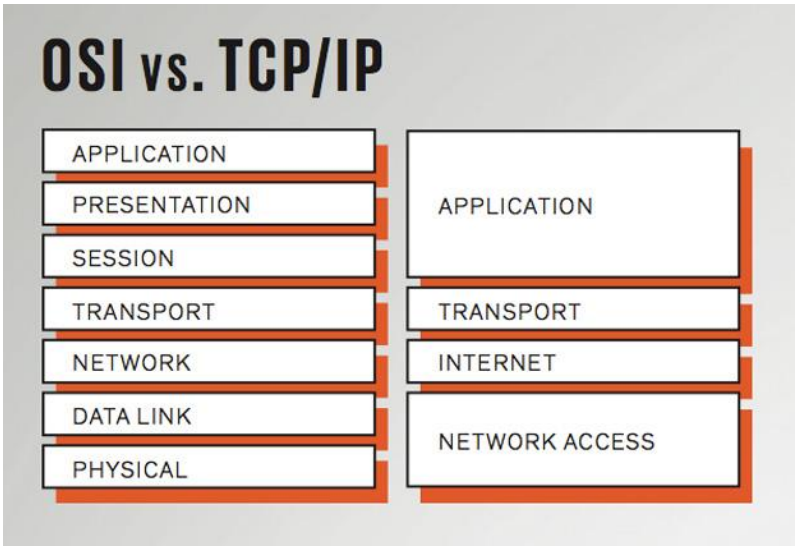

Figure 2.9 – OSI Model and TCP / IP [14]

Like is possible to see in the Mike Passwall website[15], the Application Layer can include things like File Transfers, and display formatting. HTTP is an example of an Application Layer protocol. Commonly known protocols considered by many to be part of the application layer actually may be considered to occupy the Session, Presentation, and Application Layers.

Microsoft explained in their website[16], the application layer serves as the window for users and application processes to access network services. The Application Layer contains a variety of commonly needed functions:

- Resource sharing and device redirection
- Remote file access
- Remote printer access
- Inter-process communication
- Network management
- Directory services
- Electronic messaging (such as mail)
- Network virtual terminals

Since the system to be implemented in the house will be connected to the internet and in turn to a distance family and authorities, the best protocol to be used is the TCP / IP.

In case of being some problems with the data transmission, the TCP protocol always guarantees the transmission without the loss of some data, getting always safeguarded the connection with possible family and authorities.

Eventually if this system will be implemented in a Norwegian home and since the Norwegian Health Directorate[12] is trying to change the communication platform from analogic to digital until 2018, is mandatory the use of TCP / IP protocol as a tool for Communication Protocol.

2.1.7 Structure to store information

It is assumed that the system needs few weeks to learn how to react and detect human behavior. To store the entire information collected from the sensors and cameras, the system needs storage (figure 2.10 as an example how to store information).

Figure 2.10 – Digital storage of information [17]

The basic purpose of memory, human or machine, is to keep a record of information for a certain period of time. One of the distinct things about human memory is that it's extremely good at forgetting. Forgetting is most likely clever tactic humans have elaborated which helps us to focus on the things that are immediately relevant and important in the endless clutter of our everyday lives, a way of concentrating on what really matters. Forgetting is like turning out old junk from your closet to make room for new stuff.

Computers don't remember or forget things the way that human brains do. Computers work in binary, they either know something or they don't and once they've learned, excluding some sort of catastrophic failure, they generally don't forget.

Despite the fact that collecting information about how this kind of systems work, the way how the information is stored and how all the data connect with each other has proved to be challenging, it is still believed that adequate data has been gathered to make valuable points.

The way Yuri Yoshihare et. al[2] referred in their paper, the collected information is stored in a database and visualized by the family and caregiver. The structured platform of the environment for gathering, storing, transforming, and providing information, which is called informationally structured space, is needed (figure 2.11). The technology for designing and utilizing the informationally structured space should be discussed from various points of view such as the information gathering of real environment and cyber space, the structure of the environment, and the visualization of the gathered information.

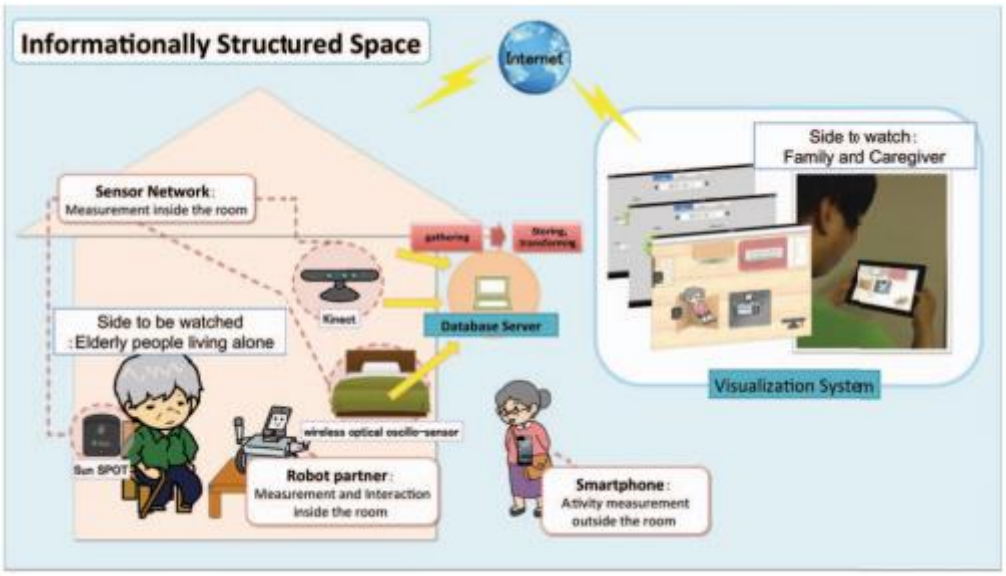

Figure 2.11 - System concept [2]

In the same paper, is suggested a way how to structure the database, which is represented on the next figure (figure 2.12). To know more about Yuri Yoshihare et. al[2] system, is advisable to read their paper.

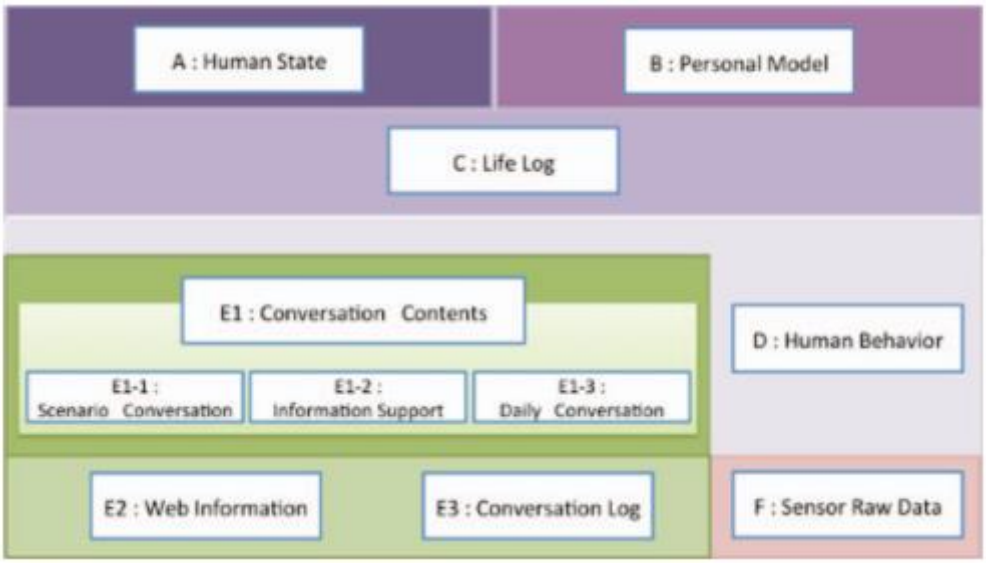

Figure 2.12 - Database structure [2]

As Marcelo Takiuchi et. al[18] mentioned in their paper, there are two sets of database: one acquisition of data and other one for active rules. The database for data acquisition is powered by resident behavior information. Every time the resident takes an action is created a new rule and stored in the database for data acquisition.

And as also mentioned in the same paper[18], is important the maintenance of the database rules.

From the solution adopted by the inhabitant, the Automation Based on Behavior system generates new rules and can create some that the system will evaluate to see if is correct, but that the resident didn't consider to teach.

The system is programmed so that the existing rules into disuse by the system are excluded automatically as soon as they reach a certain time to be set by the resident. The database stores the date of the last use of the rule, and if the rule is not used for a period of time stipulated by the resident, it is removed automatically.

If the system generates a rule that does not please the resident, he can access the system and eliminate it manually; this rule goes to a rejected database rules and when the system generate new ID3 rules, does not create this rule again. If the resident wants that rule to exist again, he needs to remove it from the rejected table rules.

Another important point in the maintenance rules, is to have a consistent database, this means prevent accidental loops; this occurs when a rule A modifies a sensor status. That change triggers another rule B, which modify the status of another sensor, which triggers the rule A again.

This problem requires a complex solution, especially when the looping happens between different rules, not just two. Is advisable to read the paper[18] to know with more detail how they used the system.

Like it was explained in TechTarget website[19] about SQL Server, a database consists in a collection of information that is organized in a way that allows being easily accessed, managed and updated (figure 2.13 as an example how it consists a database).
Databases are classified according to their organizational approach; the most prevalent approach is the relational database, a tabular database in which data is defined so that it can be reorganized and accessed in a number of different ways. A distributed database is one that can be dispersed or replicated among different points in a network. An object-oriented programming database is one that is congruent with the data defined in object classes and subclasses.

Figure 2.13 – Information store in a Database [20]

Computer databases typically contain aggregations of data records or files, such as sales transactions, product catalogs and inventories, and customer profiles. Typically, a database manager provides users the capabilities of controlling read / write access, specifying report generation, and analyzing usage. SQL (Structured Query Language) is a standard language for making interactive queries from and updating a database such as IBM's DB2, Microsoft's SQL Server, and database products from Oracle, Sybase, and Computer Associates.

As explained in the NTC Hosting website[21] (which is a web hosting) about Database, consisting in columns (fields) and rows (records) where each column contains a specific attribute and each row features a certain value for the corresponding attribute.
The number of columns within a single table depends on how many different types or categories of information is needed to store within a database, while the number of rows is defined by the quantity of the objects that have to be introduced categorized records for. This kind of simple organization of the data in database tables allows for a computer program to quickly select and handle the necessary pieces of information.

In Semih Yagcioglu and Aykut Aras paper[22], they were more specific with the way the information is stored. In their paper, they used some parts of the body and after they were being processed by MATLAB, the information was saved as MAT files and after that the application converted those MAT files into CSV files. CSV files were chosen since the file structure can be easily adapted to work with other applications and can also be used as a simple database that does not need any complex processing. The CSV files converted by the application were used to plot the body parts detected by the MATLAB pattern recognition application to see the faulty recognized body parts in frames, if there was any.

As explained in the “bigcommerce support”[23], a CSV file is a comma separated values file, which allows data to be saved in a table structured format. CSV’s look like a garden-variety spreadsheet but with a .csv extension (they can take the form of a text file containing information separated by commas). CSV files can be used with any spreadsheet program. They differ from other spreadsheet file types where is possible to have a single sheet in a file, they cannot save cell, column, or row styling, and cannot save formulas.

Y. Shafranovich[24] explained in his document, Comma Separated Values format (CSV) has been used to exchanging and converting data between various spreadsheet programs. Showing with that, the CSV format is a “smart” way to store information which allows the use by different programs. Y. Shafranovich[24] also referred the security considerations by using CSV format; CSV files contain passive text data that should not represent any risks. However, it is possible in theory that malicious binary data may be included in order to exploit potential buffer overruns in the program processing CSV data. Additionally, private data may be shared via this format.

Dominic John Repici and David Burton[25] mentioned in their document CSV files use a simple ASCII character encoding and is capable of enclosing pure binary data fields. As long as does not exist any application level software making assumptions about the data in the fields, CSV fields can safely contain all 256 binary octets as basic binary data. The binary data may represent utf-16 characters, or it may represent a photograph, is the same for CSV files.
There is nothing inherently wrong with using CSV to maintain data written in alternate character encodings such as utf-8 and utf-16. CSV's syntax is durable enough to deal with these encoding schemes.

In the International Monetary Fund[26], is mentioned data tables can also be presented in Comma Delimited, CSV text file format, which allows the data table to be easily retrieved into a variety of applications, easily manipulate data that is in columnar format.

With this two possible ways to store information, just depends the amount of data is going to be store, to choose a good way to store the information.
Since the data to be store in this situation, is just the inhabitant daily routines, schedules with the behaviors or activities, is more advisable to store the information using text files, in this case, CSV files, where the rows represent each day and the columns the time, the behavior or activity is doing at that time.
As a result of the research that was conducted about the way to store information, was decided to use CSV files; less complex system and for the amount of information to be stored, was the best choice.

Chapter 3

Methods to infer a person activities and behaviors from the sensors

In this chapter it is presented the methods studied to infer a person activities and behaviors.

It is also presented the ID3 algorithm.

3 Methods to infer a person activities and behaviors from the sensors

The behavior can be described as basically what the individual does with respect to the environment he or she lives in and the relation with other individuals.
Human behavior is the expression of the action expressed by the result of the interaction of various internal and external factors which we live, such as personality, culture, expectations, social roles and experiences.

One of the most important things to clarify, are the person “activities” and “behaviors” in order to avoid confusion with the inhabitant actions.
For an example the activities “walk”, “stand up”, “lay down”, “sit”, can have different behaviors. The activity “walk” can be used by the inhabitant to go to the toilet, to go to the kitchen, to go to the living room. The inhabitant can be standing up from the bed in the morning, or standing up from the sofa while he was watching TV.
With the activity “lay down”, the inhabitant can lay down on the bed in the bedroom, or on the sofa in the living room, or somewhere in the floor (in case if something is wrong).
The same happen with the activity “sit” where he can sit on a chair in the kitchen, on a chair in the living room, or in the sofa in the living room (figure 3.1).

Figure 3.1 – Example of activities and behaviors. Walking, sitting in the chair, standing up from the chair [27]

Like Pau-Choo Chung and Chin-De Liu[28] explained in their report, is important to consider the context because plays an important role in behavior understanding.

The system that will be implemented in the house is an “Automation Based on Behavior”. An automation system must adapt and learn with the user and will construct decisions trees based on the behavior of the inhabitant. As an automatic mechanism, its decisions are based on artificial intelligence techniques and uses ID3 algorithm.

In order to construct the human behavior, can be used different methods, such as: Fuzzy Logic, Neural Networks and Markov method.

As Alexandre Garcia Aguado and Marco André Cantanhede[29] explained in their paper about Fuzzy Logic, this method is highly recommended to use when a specific problem has a high degree of uncertainty. For a problem like this, was necessary to be used a mathematical model that addresses this specificity and not disregard aspects that can be ignored by applying traditional logics. For Alexandre Garcia Aguado and Marco André Cantanhede[29], Fuzzy Logic is a model capable of combining the imprecision associated with natural events and the computing power of machines producing intelligent response systems.
One of the major objectives inherent with the Fuzzy Logic is approaching in your logic, to the way which human related information by seeking answers to problems, so the major focus of this logic is to find solution to the problems with uncertain present information.
The behavior presented by Fuzzy Logic has great similarities to way humans process information, is not boolean but bringing inferences and approximations. This feature makes the Fuzzy Logic is widely used in Artificial Intelligence models where it always seeks this closeness of human behavior.

Like was possible to read in the Universidade de São Paulo website[30], the most important property of Neural Networks is the ability to learn from their environment and thus improve their performance. This is done through an iterative process of adjustments applied to their weights, the training. The learning process happens when the Neural Network reaches a general solution for a class of problems.

The learning algorithm is called a set of well-defined rules for the solution of a learning problem. There are many specific types of learning algorithms for certain types of Neural Networks, the mainly difference in these algorithms is how the weights are modified.

Another important factor is the way which a Neural Network is related with the environment. There are the following learning paradigms:

- Supervised learning: when an external agent indicate to the network the desired output to the standard input is used;
- Unsupervised learning (self-organization): when there is no external agent indicating the desired output to the input patterns;
- Reinforcement: when an external critic evaluates the output provided by the network.

Like is referring in Daniel Makoto Tokunaga and Cléber Gimenez Corrêa paper[31], Artificial Neural Networks are parallel systems composed of simple processing units, layered and highly interconnected, built based on the human brain. This type of system is a different way of designing computer systems that do not run programs, but behave, react, organize and learn, acquiring generalization ability.

Like Daniel Makoto Tokunaga and Cléber Gimenez Corrêa[31] explained in their report, Markov processes can be classified into finite and discrete states, with the probability of transition between these states, on a discrete time interval, depending only on the current state and the next state. Following states following this process are named Markov Chains.
Markov Chains model are interesting tools where knowledge of the state model, but with uncertainties in state transitions.

A widely used technique for modeling human based on stochastic methods is the Hidden Markov Model. The Hidden Markov Model is a temporal model which depends only on the observation of people's actions. Another great feature is the fact that also allows the model to be trained by people in order to capture its features.

As Adam N. Sanborn et. al[32] explained in their paper, a Markov Chain is a sequence of random variables where the value taken by each variable depends only on the value taken by the previous variable. Is possible to generate a sequence of states from a Markov Chain by iteratively drawing each variable from its distribution conditioned on the previous variable; the distribution expresses the transition probabilities associated with the Markov Chain, which are the probabilities of moving from one state to the next. After many iterations, the probability that a Chain is in a particular state converges to a fixed value, the stationary probability, regardless of the initial value of the Chain; that stationary distribution is determined by the transition probabilities of the Markov Chain (figure 3.2).

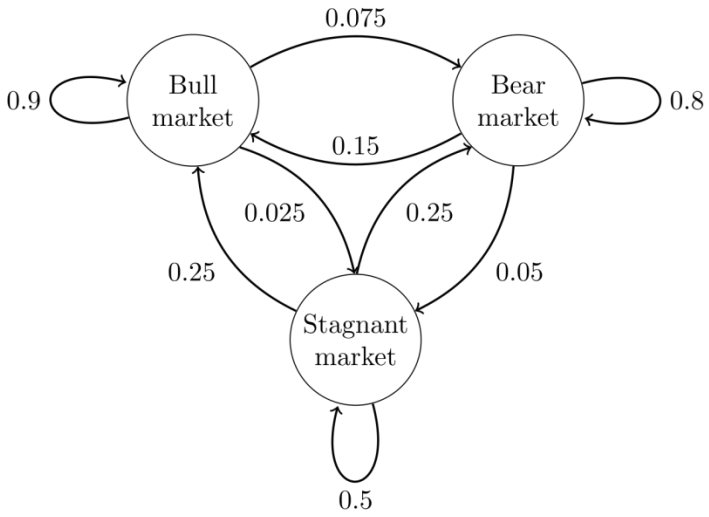

Figure 3.2 – Example of Markov Chain Monte Carlo [33]

There were some studies which was used a combination of 2 methods, the Fuzzy Logic and the Neural Network Methods.

While Neural Network is good at pattern recognition, it is not good to explain how to make the right decisions.

Fuzzy Logic deals with inaccurate information, is good to explain is decisions, but it cannot automatically acquire the rules that is use to make the decisions[34].

To combine these 2 methods is important in order to suppress the individual limitation of each method (chapter 3.4).

All the methods have advantages and disadvantages. To use the Neural Network, Fuzzy Logic or Neural-Fuzzy is important to have the inhabitant daily routine from a lot of days before (as much information more precise will react the system).

Like Adriano Zanette et. al[35] explained in their paper, the use of Fuzzy Logic was an advantage because was a method which allows better treatment of inaccuracies, provided a fast prototyping systems and simplified the acquisition of the knowledge. On the other hand was a system which was impossible to describe reality in its entirety using only the extremes, only the false or true, the inference modeling was hampered, did not apply to transactions with subjective concepts and also important to have rules to know when an action occur which was supposed to happen, which made this method inaccurate.

The Neural Network method, like Fernando Osório[36] explained in his document, allowed an automatic acquisition of empirical knowledge from a basic learning examples relating to a problem and also great power to represent the knowledge by creating relationships between the weighted system entries. But this method also had disadvantages, slow learning and adaptation process, difficulty with the network configuration in relation to its initial structure and also in regard to the learning algorithm parameters and also difficulties with the convergence and instability inherent in optimization algorithms employees.

One of the major advantages of Bayesian statistics (Markov Chain Monte Carlo method) according to Marcos Jun-Iti Yokoo et. al[37], was the use of additional information, prior information than studying. The priori knowledge was most important when the available information was scarce or little informative. An obvious disadvantage, like Stephen P. Brooks[38] explained in his paper, of this approach was the computational burden associated with running n parallel chains, which may be prohibitively high in many practical applications; this problem may be overcome in the case where the state space had a partial ordering.

3.1 ID3 algorithm

Like Diana Colombo Pelegrin et. al[39] explained in their paper, the ID3 algorithm uses logic and mathematics to process, organize and simplify a large data set. It also has the ability to operate non-numeric data, being a difference between it and methods statisticians, because while the ID3 assumes nominal attributes, statistical methods using numerical attributes.

According with the paper[39], the ID3 algorithm uses the measured gain information to reduce the value of the output object uncertainty. The information gain is a statistical measure used to construct the decision tree in order to choose the test attribute among all involved with the node in question. The attribute with the highest information gain is the one that best ranks the set of training samples. Therefore, the use of the concept of information gain enables to reduce the final depth of the decision tree.

As Vitor Lins and Waldson Moura[7] referred in their paper, the ID3 algorithm is a learning technique that involves the induction of an overview from a set of samples, called training set.

It is one of the simplest algorithms that generalize rules in the form of a tree decision. In ID3, each rule is a set of instances, which has certain discrete attributes.

An example of these instances can be “blinds” where the attributes would be “open”, “closed”, “up”, “down”. The “time” can also be another example of instance where its attributes would be “morning”, “evening” and “night”.

To create the decision tree, the ID3 uses a formula that calculates the entropy of a training set (entropy - thermodynamic quantity that measures the part of energy which cannot be transformed in to work). The entropy measures the amount of information contained in an attribute. Lower the entropy of an attribute, the lower their degree of uncertainty. Therefore, the highest entropy is the attribute that has the highest amount of information, being chosen to be the root of a Decision Tree.

With this calculation, is possible to determine how many examples for each response attribute. The ID3 ranks each attribute of each instance relating to each response attribute.

The system should choose an attribute as root of the decision tree that can separate in the best possible way, the initial training set in other training sets smaller but more homogeneous.

The best gain on an instance means that if is possible to split the training set in more homogeneous subsets of the other instances that have gain lower value. Thus, the ID3 can decide which will be the nodes and the root of the decision tree.

The ID3 when applied to the automation system involves the following definitions:

- Training set: each training set on the ID3 system would be an automation actuator
- System response: each response attribute of a training set in the ID3 system will be a state actuator whose training set is.
- Instances and attributes: each sensor of an automation system is an instance whose attributes form the status of this sensor.

In order to get more detail information related with this topic, it is advisable to consult the paper[7].

The Automation Based on Behavior system consists of actuators, sensors and a database with rules created by ID3:

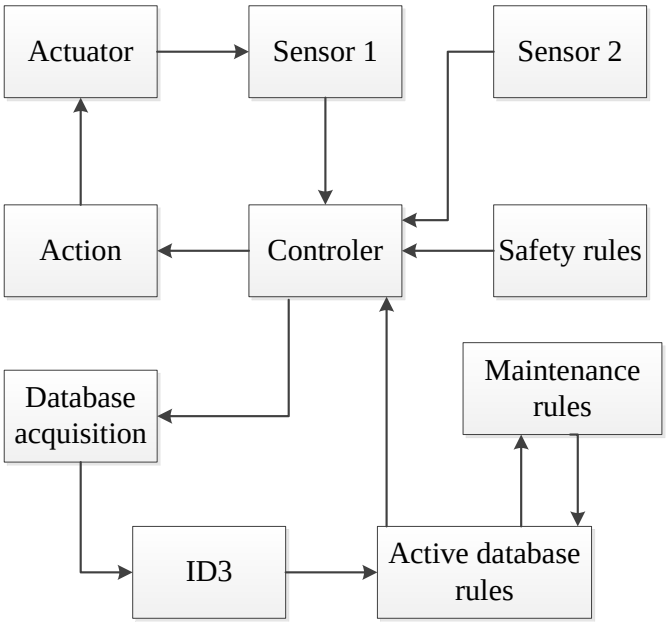

Figure 3.3 - Automation Based on Behavior system

As mentioned in Marcelo Takiuchi et. al paper[18], the choice of ID3 algorithm was given for its simplicity and its high power of generalization rules, where each rule is a set of instances which has certain discrete attributes.

The rules for the ID3 algorithm in the training set are generated from a database from all actions taken by the resident. Whenever the status of a sensor changed, and this change is not caused by the action of a rule, will be set to the system a new behavior to be learned. Because of this, is important to keep on the database a rule whit all sensors status and with the action that results in the change of status detected.

The system works with databases that store the configuration of the automation rules.

The ID3 algorithm is triggered every time the data bank of a certain actuator reaches a generic number of rules to ensure a good sampling behavior. The use of ID3 transforms generic rules of behavior in active, specific rules based on the resident behavior. The ID3 alone, determines the relevant sensors status and responsible for the analyzed behavior.

The new rules generated by ID3 are stored in the database of active rules and are normally used by the controller.

To build the decision tree, there are some techniques that examine and compare the class distribution during the tree construction, as Simone Garcia and Luis Alvarez[40] explained in their paper. The result obtained after the decision tree construction, are organized data in compact form that are used to classify new cases. It builds decision trees from a set of given examples and the result is used to classify future samples. After building a decision tree, is important to evaluate it; this evaluation is carried out using data that has not been used in training. This strategy allows us to estimate how the tree generalizes the data and adapts to new situations, it can also estimate the proportion of errors occurred and successes in the tree construction.

Like António Santos and Hélder Ferreira[41] referred in their paper, the advantage of this algorithm compared to the others, is that incorporates a method to allows it to build a decision tree "minimum", through a choice of most discriminating attribute for each branch of the tree.

The way to choose the most discriminating attribute is based on the rule of choice: must choose the split attribute the one that produces greater information gain. Considering the node with label A, the best attribute is one that minimizes E (A).

$$E(A) = \sum_{i=1}^{v} \frac{pi + pn}{p + n} I(pi, ni)$$

Where,

E - information gain

P, N - subsets of all possible nodes of the tree

3.2 Fuzzy Logic

Bo Yao et. al[42], in their paper, presented a system based on Interval Type-2 Fuzzy Logic System for robust human behavior recognition using machine vision in intelligent environment (figure 3.4). It was a robust framework, which had an inherent representational power to deal with the high levels uncertainties available in real-world problems.

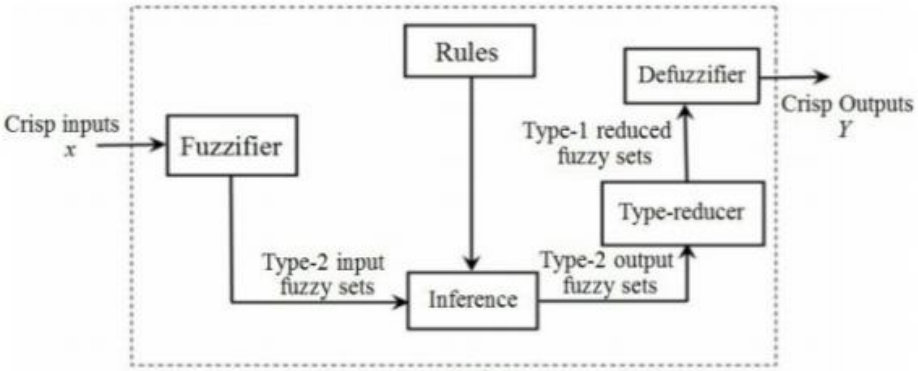

Figure 3.4 - Structure of the Type-2 Fuzzy Logic System [42]

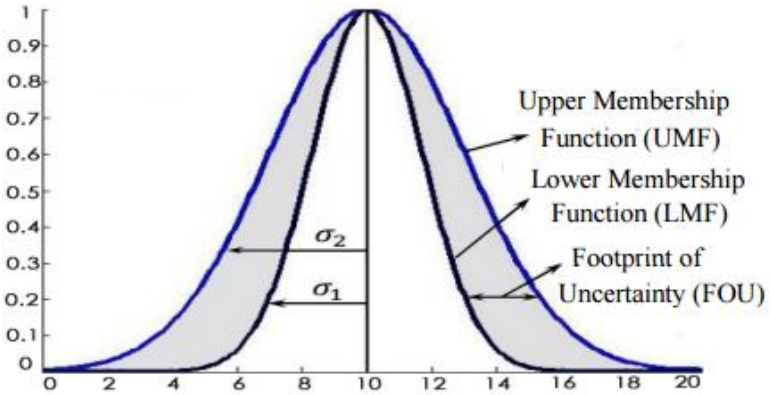

Figure 3.5 - Interval Type-2 Fuzzy set [42]

According to Bo Yao et. al[42], the recognition process was by the human silhouette, which was called frame, was detected and extracted using Interval Type-2 Fuzzy Logic System (figure 3.5). After the frame was extracted, input feature vectors for the Fuzzy-

based recognition method were computed based in a model based feature set to describe the shape and motion characteristics.

The Type-1 Fuzzy Membership Functions (MFs) of the inputs to the Fuzzy Systems were learned via Fuzzy C-Means clustering. The Type-2 Fuzzy MFs used in the system were produced by using the obtained Type-1 Fuzzy sets as the principal membership functions which were blurred by a certain percentage to create a given Footprint of Uncertainty (FOU), (figure 3.6).

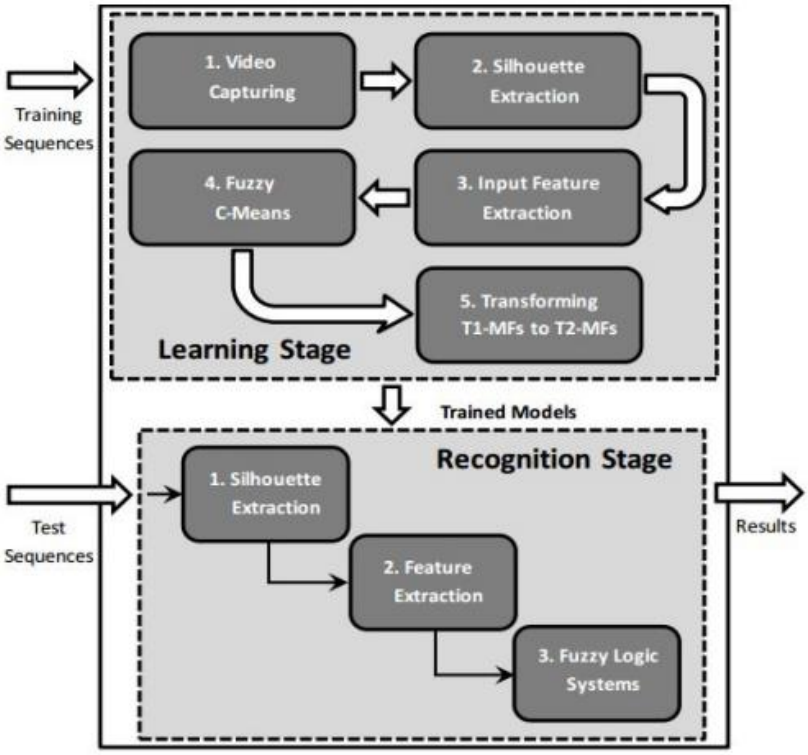

Figure 3.6 - System proposed by Bo Yao et. al [42]

When extracting the frame by using the proposed method, Interval Type-2 Fuzzy Logic System, had an improvement of 8,26% when compared with the Type-1 Fuzzy Logic System. They had a worst image, the pixels were reduced to 5,71; but was possible to correct the image when just a person was in the image (figure 3.7).

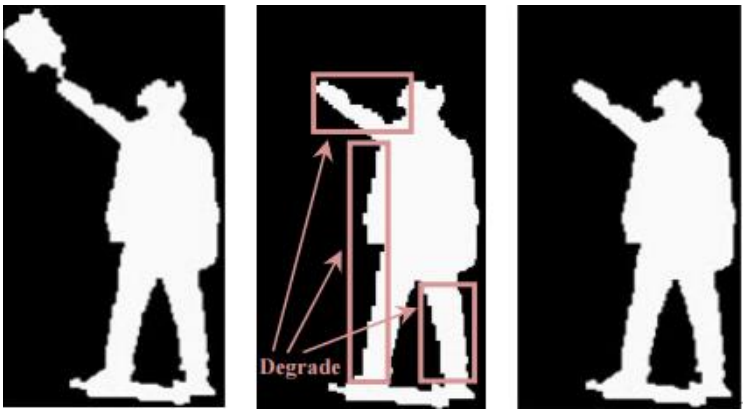

Figure 3.7 - Experiment results of silhouette extraction [42]

For inputs in their system, they used 7: motion speed in horizontal direction, motion speed in vertical direction, area ratio of the silhouette's head, area ratio of the silhouette's right hand, area ratio of the silhouette's right leg, area ratio of the silhouette's left hand, area ratio of the silhouette's left leg. All the inputs were represented by four Fuzzy sets: Very Low, Low, Medium and High. The Fuzzy System's output was the behavior possibility, which was represented by two Fuzzy sets, Low and High.

They had to transform the Type-1 Membership Functions into Interval Type-2 Membership Functions. The Interval Type-2 Fuzzy set Footprint of Uncertainty (FOU) was bounded by two membership functions, Upper Membership Function (UMF) and the Lower Membership Function (LMF). In order to construct the Type-2 Membership Function modelling, was transformed the Type-1 Fuzzy set to the Interval Type-2 Fuzzy set with uncertain mean.

For the experience, they tested the Type-1 Fuzzy Logic System and the Interval Type-2 Fuzzy Logic System by using the Weizmann human action database.

As a conclusion of using the Interval Type-2 Fuzzy Logic System they got an average recognition per-frame accuracy of 98,12%, which was better 4,09% compared with Type-1 Fuzzy Logic System. The system also provided a relatively computationally efficiency and a robust real-time response.

For more detail information, is advisable to consult the paper[42].

Juan Martinez-Miranda et. al[43], used in their paper the Fuzzy Logic method in order to get a human behavior model, to study the challenge of work team configuration.

The method proposed was an agent-based model to simulate the interaction of a team member with other team members and with the tasks of a project; in particular was a development and implementation of a Geographical Information System (GIS) for internal use at Mexican Petroleum Institute (IMP).

To achieve the first step of team behavior simulation was considered the relevant human characteristics that affect the performance of a person in a specific project: cognitive capabilities, personality trends, emotional states and social characteristics. The behavior of a person was generated by the combination of these characteristics.

According to Juan Martinez-Miranda et. al[43], the main goal was to design a unified control architecture able to combine the interesting properties associated to “intelligence”, such as reactivity, planning, deliberation and motivation. The model dealt with three negative emotions: fear, pain and anger.

To test and for validation of the model, was used the IMP’s research and technological development center. In order to adapt the agent-model to IMP, they interviewed project managers to know how they selected people to work in each project and was noticing the characteristics used by the project managers to choose each person for a project, were similar to their model.

Despite the results were depending on the rules configuration, the simulation and the GIS / IMP project results were similar, they had some difficulties: lack of information from all team members involved in the project, lack of communication between the project manager and some team members.

The method implemented was to model human behavior at work, using Fuzzy Logic to represent a set of selected human characteristics that influenced the performance of a person when got a project. Even with positive results of the initial validation, was concluded that was necessary more tests to improve the overall validation of the model.

In order to get more detail information, is advisable to consult the paper[43].

The figure 3.8 shows an example how to use Fuzzy Logic with temperature (cold, warm and hot).

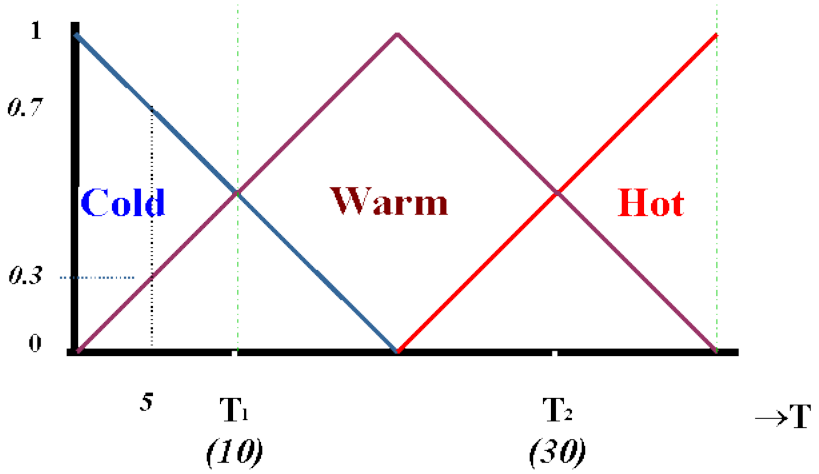

Figure 3.8 – Example how the intervals of Fuzzy Logic works, in this case related with temperature [33]

3.3 Neural Networks

How António Santos and Hélder Ferreira[41] explained in their paper, Neural Networks are based on the knowledge we have about how work the neurons in the human brain (figure 3.9).

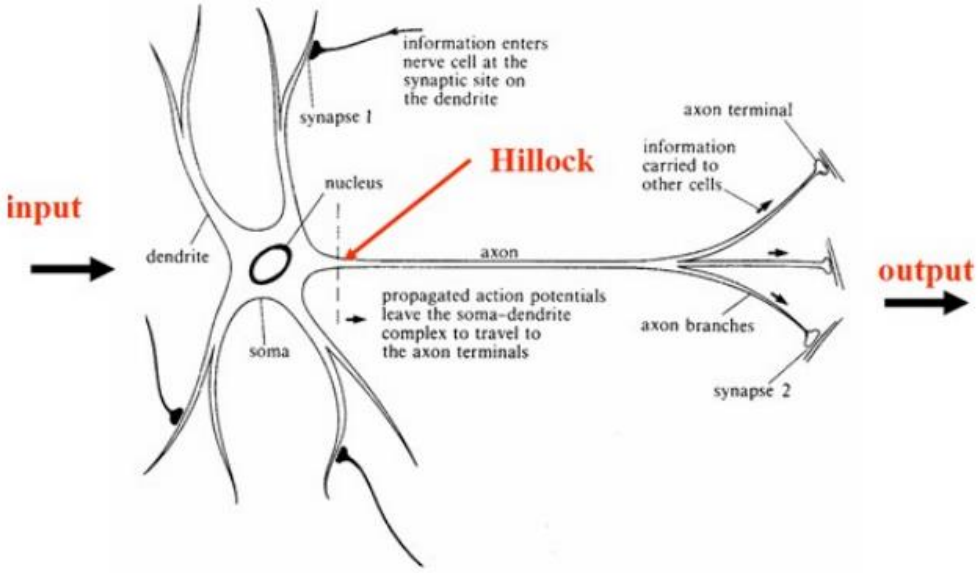

Figure 3.9 - Biological neuron [41]

The artificial Neural Networks are used in many areas of artificial intelligence research and are successful in pattern recognition, process control and robot control.

Neural Networks are based on the use of artificial neurons. These artificial neurons are software which in general terms could be represented like this:

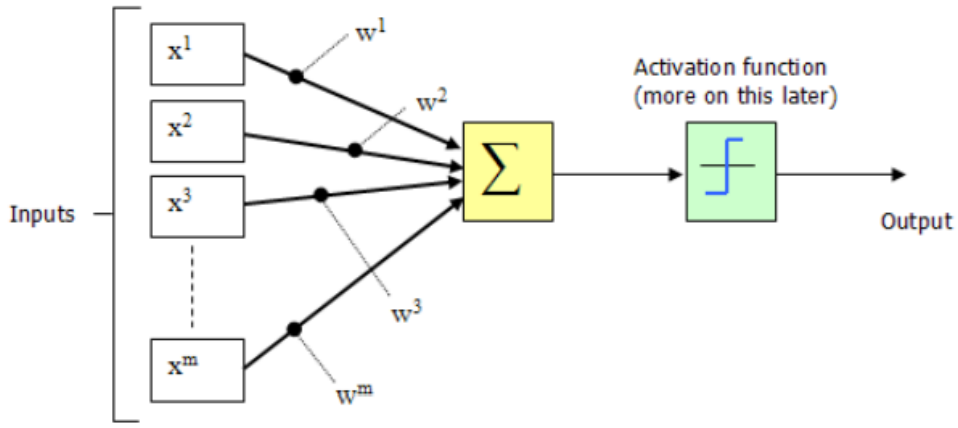

Figure 3.10 - Possible generic representation of artificial neurons [41]

The input lines represent data input lines, usually sensors or other artificial neurons. Associated with each row there is a variable that quantifies the "importance" of this line, is “weight”. The square with the inside Σ represents a sum of inputs function. In this function, the sum of all individual inputs associated with their weights will be compared with a threshold value above, which the neuron will activate the output.

The network learning is achieved by adjusting the values weights associated with each input neuron. The neuron "decision" is a function of what he receives in all its inputs (from neighboring neurons) and compared with an activation function (which defines the form of neuron activation). However, each input has a weight associated with simplicity, is the importance of this input to the neuron.

If after calculating the weighted sum of all inputs, the neuron decides which will be activated, it will modify (increase) the weight of all inputs that were "in favor" of activation; this increase is due to rate learning. This will make future decisions on inputs that "hit more often" have greater weight in the decision of each individual neuron.

In case of being in a neuronal network training situation, the real and correct value is known and can be incorporated into the how the network learns.

As Marie Chan et. al[44] referred in their paper, they installed the system in an institution for elderly and disable people and they used Artificial Neural Networks for the system to learn the inhabitants daily habits. All the sensors and the computer were connected using a binary unit system (BUS). How they explained, each Artificial Neural Network was in itself a dense interconnection between the formal neurons which constitute the information processing units having currently nonlinear transfer functions and act in parallel (figure 3.11). They considered as an advantage of the Network because they can be used as "black boxes". The Network can model any system without a priori knowledge of its internal function. Was adequate to have a set of Input / Output vectors from the experiment and was characteristic of the task to be modelled and constitute the learning database.

For Marie Chan et. al[44], learning was the procedure that consisted of finding and adapting the parameters of the Artificial Neural Networks in such a way that the process to be modelled was as much approximated as possible. The network was defined by the type of the formal neurons, the architecture of the connections and the learning rules. Neurons after being activated as a function of the input data transmitted their activation to the other neurons to which output was connected.

There were three functions: an input function which was the weighted sum of the input data and the weights of the network, an activation function which was a sigmoid and the output function was a linear function.

As architecture they had chosen the one where the neurons were arranged in layers and where the activations propagated from layers to layers up to the output layer with only one hidden layer.

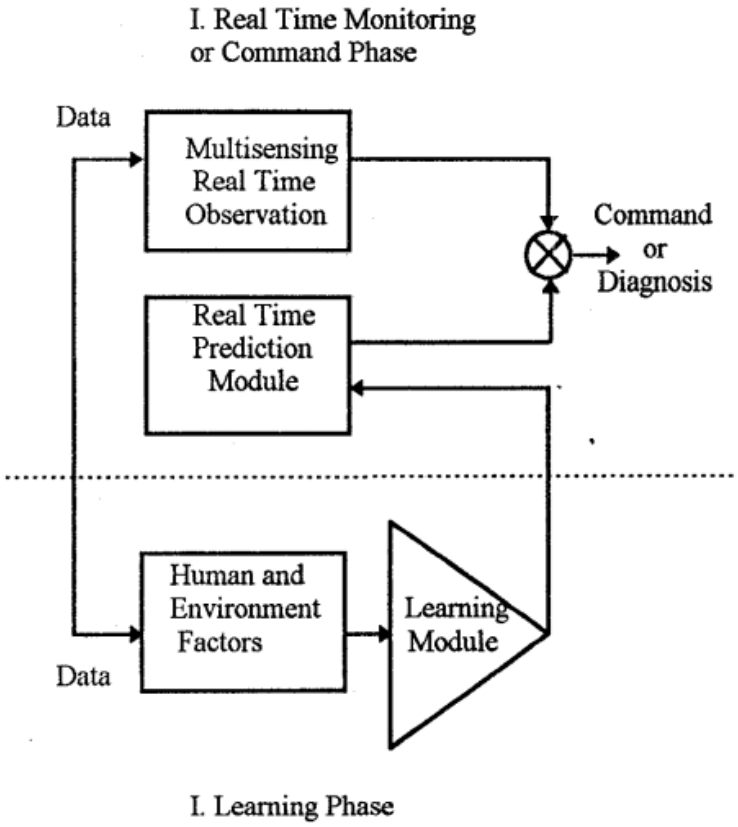

Figure 3.11 - Principle used [44]

Demetrios Koutsomanis[45], like explained in his paper, used Neural Network method to predict human behavior. He compared observed information with the prediction from Neural Network after adequate training.

The observed information was collected from a hospital's refectory during 1 year. His aim was to predict who was in a specific place and doing what.

As input to train the Neural Network, he tried to identify the most factors that were likely to influence the choice of the individual to perform certain actions, such as occupy the refectory. Had some difficulties while was collecting information, because some patients changed a lot their behaviors, which was difficult to maintain a pattern.

The methodology he used was ethogram and transcribed in Excel before being transformed into ASCII file, for after being used as input to train the Network. After the training, he compared the output with the observed information collected during 1 year.

He concluded there were no significant differences between the observed data and the one from Artificial Intelligence, which proved the Neural Network was a powerful tool to be used in the prediction of human behavior.

For more detail information, is advisable to consult the paper[45].

In Tjeng Wawan Cenggoro and Awanga Harsa Kridalaksana paper[46], they used the Artificial Neural Network method in order recognize the human behavior pattern in "Paper-Rock-Scissor game".

Was studied the effectiveness of backpropagation of Artificial Neural Network method in recognizing human behavior pattern in paper-rock-scissor game by a computer; was described how the method was learning the behavior pattern of a human and how could give a correct response to the future match against the human, increasing the computer winning percentage on the future paper rock scissor game against him.

It was used 4 neurons as input, considering the choices made by the computer and the research object in two consecutive matches. As an output was considered one neuron which produced output as the predicted choice, which was made by the research object in the match right after two matches.

In order to generate randomly choices by the computer was performed 40 paper-rock-scissor matches between the computer and the research object. The system started to learn the process just after the third match, because it needed the first two as inputs.

They concluded the system could learn the process and increasing the winning rate, against the research object based only on observation.

In order to get more detail information, is advisable to consult the paper[46].

Champa H. N and Dr. K. R. Ananda Kumar[47] studied in their paper Artificial Neural Network for human behavior prediction through handwriting analysis. Was proposed a method to predict the personality of a person from the baseline, the pen pressure and the letter "t" as found in an individual's handwriting. To the Artificial Neural Network inputs were used these parameters. For the output was the writer's personality trait.

Was used the polygonalization to find the baseline slant from a single line in the handwritten text. Related with the pen pressure was calculated counting the black pixels which evaluated the writer emotional intensity. The lower case letter “t” revealed accurately information about the writer, his or her self-esteem.

Because the enormous feature data (according with the inputs, they had 30 different personalities), the use of Artificial Neural Network was needed for automated prediction.

The system used allowed the user to select the required character from the input image for feature extraction.

For more detail information, is advisable to consult the paper[47].

Ming Jiang and Sen Qiu[48] proposed in their paper the use of Probability Neural Network to monitoring human behavior by relearning the network.

The method used had some good relearning features, could be easily updated from new training data to improve the accuracy and could improve the robustness against label errors.

The experiment took place at Intelligent System in Dalian University of Technology laboratory. Were used 5 signal collection nodes placed at 5 body parts (lower left forearm, lower right forearm, waist, left ankle, and right ankle) and the signal reception node attached to a computer. A tri-axial accelerometer (ADXL330) was integrated in a signal collection node, which could measure acceleration with a minimum full-scale range of ±3g. Were used 4 males which they had to perform some daily behaviors such as: standing, sitting on a couch, lying on a bed, walking around, going upstairs, going downstairs, sweeping the floor, wiping a table, putting on a vest and taking off a vest.

Based in their experiment, they concluded the method obtained a satisfactory performance for long-term monitoring applications.

For more detail information, is advisable to consult the paper[48].

3.4 Neural-Fuzzy

In Hideki Hashimoto et. al paper[49], where they studied the human behavior (represented by a robot) in an environment surrounded by objects, they used Fuzzy-Neural Network in order to approximate observed human behavior, with observation data clustering with the purpose of extract important training data from observation.

As they explained, they applied Fuzzy-Neural Network in the behavior approximation framework to handle the non-linear mapping of target tracking, obstacle avoidance and action selection. The input used was the local space and the desired target point and for output, they used the moving vector (figure 3.12).

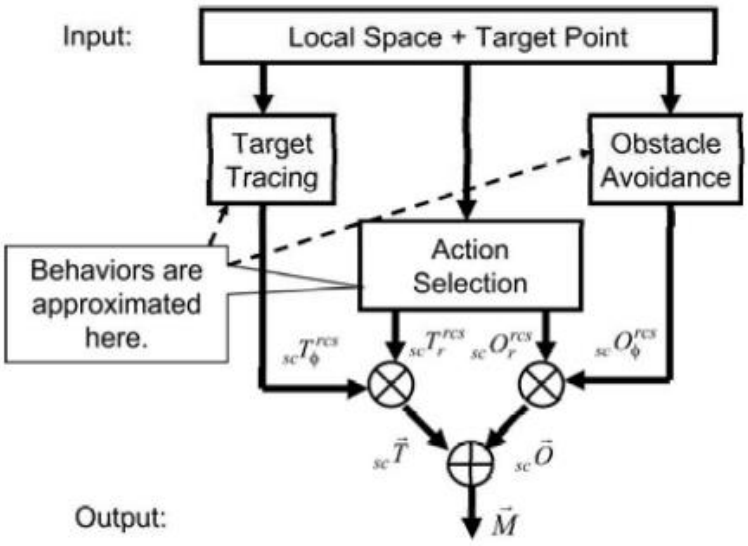

Figure 3.12 - Behavior approximation framework for human walking behavior [49]

The modeling of Fuzzy-Neuro had been explained by Hideki Hashimoto et. al[49], was a branch of system identification and involved two phases: structure identification and parameter identification. The structure identification was related to finding a suitable number of rules and a proper partition of the input space, with proper membership functions. The parameter identification was the adjustment of linear coefficients.

After the structure of the Fuzzy-Neural Network was defined, the system started to learn in order to tune consequent parameters of the linear sub-models. The Fuzzy-Neural Network output was linear in the parameters of the consequent linear models, thus those linear parameters were identified by linear least-squares-method.

Also in their paper, they made a little experiment where a teacher avoided collision with some other person by changing his heading and velocity (figure 3.13).

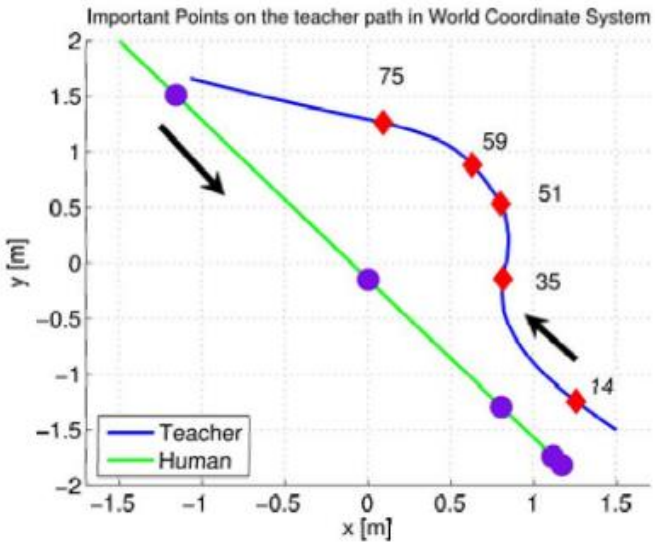

Figure 3.13 - Teacher and other person path in world coordinate system [49]

After the selection of the observed points, the training of the Fuzzy-Neural network took place, according to the proposed behavior approximation framework.

As input of the Fuzzy-Neural Network they used features of the local space, extended with the relative target vector in polar coordinate, for target tracing and action selection behavior. For output, they used the direction of the scaled obstacle vector for obstacle avoidance, the direction of the scaled target vector for target tracing and the length of scaled target vector and scaled obstacle vector for action selection.

T. R. Chandrashekhar et. al[50], applied Fuzzy Logic to determine the characteristic of human face using facial components. They used a software development kit from Intel which they introduced in December 2012, which redefined the human computer interaction by multimodal human perspective detection; included: face detection, facial landmark point detection, facial attribute detection, hand tracking, object tracking, gesture tracking system and voice recognition system.

The system used 2D and 3D tracking, but T. R. Chandrashekhar et. al[50] just used the 2D images. The system developed by Intel implemented the algorithm with C++ and T. R. Chandrashekhar et. al[50] proposed with C#.

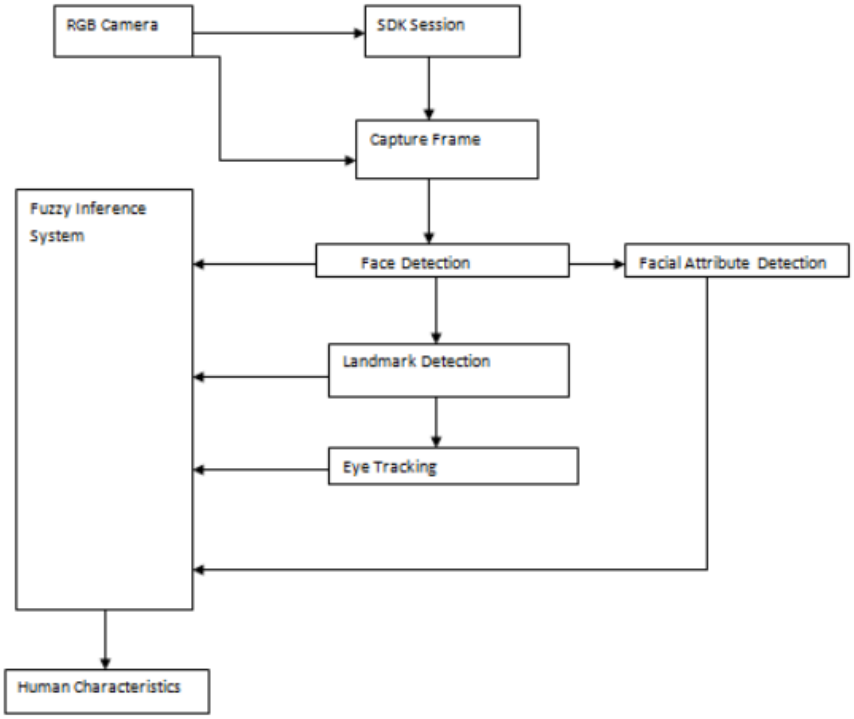

Figure 3.14 - Block diagram of the system [50]

It is explained in the picture how the system works (figure 3.14). Through the RGB camera and the by the SDK Session or by Capture Frame, was analyzed the person's features; after that analysis the information was processed by the Fuzzy System which will give the Human Characteristics.

Although the results weren't perfect, they were very satisfactory. When they tested isolated images they had 65% accuracy for smile detection; related with the age analysis had 60% accuracy, but that percentage changed depending the distance from the camera. When the results were accumulated and aggregated over a longer period of time, the outcome was quite efficient.

It was concluded that it was possible to improve the system by using custom detection techniques in association of SDK algorithms and also by applying depth map based detection alongside RGB data based detection.

Giovanni Acampora et. al[51], studied a semantic human behavior based on Neuro-Fuzzy approach, regardless the specific application, could tracking kinematic data into a collection of semantic labels characterizing the behavior of different actors in a scene in order to appropriately classify the current situation.

Was defined behavioral taxonomy the mapping between labels and human activities, a hierarchical structure useful for identifying the different components characterizing a given behavior and how these components interact with the application scenario. The behavioral taxonomy vision allowed specifying human behaviors in a well-defined and structured way by depicting a collection of behavioral components whose detection and aggregation could enable a full scene understanding and characterization.

The method proposed used Time Delay Neural Network (TDNN) capable of classifying 4 different classes of trajectories: walking, running, loitering and stopping. TDNN evaluated human micro-behavior by computing a real value; from the collection of real values were used as an input vector to a Fuzzy system which modeled each trajectories class by a Fuzzy concept composed by a single Fuzzy set and used additional Fuzzy variables for modeling the context features such as can be considered the distance among different people or the distance between a human being and a significant object in the scene.

The Neural-Fuzzy approach examined different classes of features: temporal features and contextual features. As a database was used Benchmark Data for PETS-ECCV, with some different scenarios acquired in real world environment. From the data, were used 60% to train the Neural Network and the rest to test the system.

The proposed approach detected human behaviors by means of a hierarchical analysis capable of identifying and labeling the different components of a complex behavior, correctly classified in the 100% of the cases, although with different reliability value, ranging from 0.6 to 1.

For more specific information, is advisable to consult the paper [51].

3.5 Markov Chain Monte Carlo

According to Alex Pentland and Andrew Liu[52], a model of human behavior can be used to produce improved human-machine systems. If the machine can recognize the human's behavior or, even better, if it can anticipate the human's behavior, can adjust itself to serve the human's needs better. To be able to do it, the machine needs to be able to determine which of the human's control states is currently active and to predict transitions between control states. For this to be possible, they adapted the expectation-maximization methods developed for use with Hidden Markov Models.

In their study, they could recognized human driving behaviors accurately and anticipated the human's behavior for several seconds into the future.

In their case, since they analyzed the driver's behavior, they had to divide his behavior into several prototypical behaviors, such as a relaxed driver or a very tight driver; for that they used the Markov Dynamic Models. After observed the driver's behavior, determined the best model to fit into the driver behavior and for that a mathematically expression was used (for more detail information consult the paper[52]):

$$\hat{\mathbf{X}}_k^{(i)} = \mathbf{X}_k^{*(i)} + \mathbf{K}_k^{(i)}(\mathbf{Y}_k - \mathbf{h}^{(i)}(\mathbf{X}_k^{*(i)}, t))$$

According to the paper, the initial topology for a Markov Dynamics Models can be determined by estimating how many different states are involved in the observed phenomenon; setting the topology can be performed empirically.

It was shown four states which described a driver's behavior. Each state had sub states to describe the fine grain structure of the various behaviors (figure 3.15).

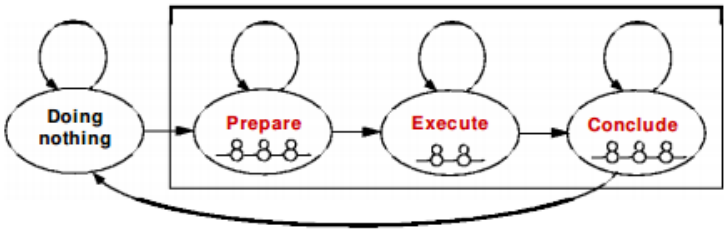

Figure 3.15 - A Markov Dynamic Model of driver action. Only the sub states in the prepare state will be used for action recognition [52]

In their experiment, it was used a driving simulator where were controlled the steering wheel angle and velocity, car velocity and car acceleration. Commands were presented on the screen (for more detail information consult the paper). All of the information and driver reactions were recorded on the computer and later analyzed (figure 3.16).

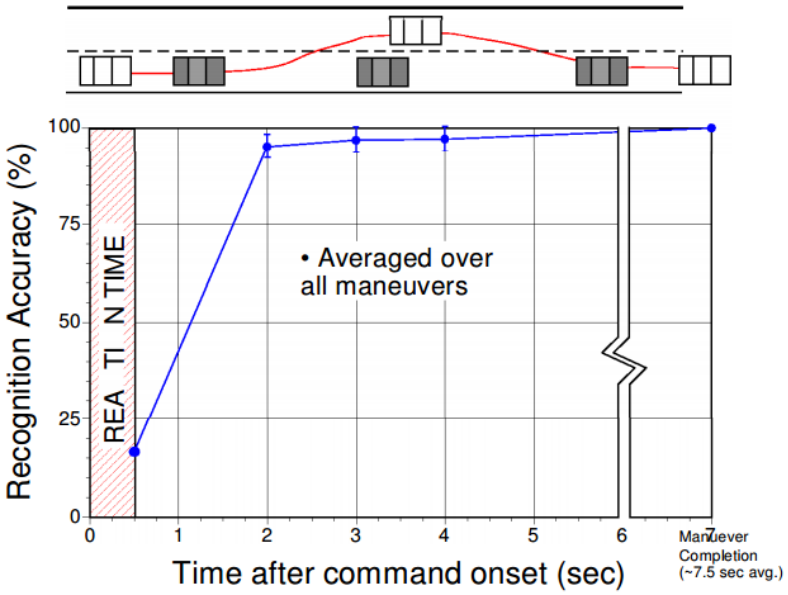

Figure 3.16 - Recognition accuracy versus time [52]

They concluded, like they mentioned in their paper, a human action was better described by using sequence of control steps instead of raw positions and velocities. Despite the positive results, they advised caution when transferring them to the "real world", because the number of different styles to drive a car.

Like Paulo Renato Alves Firmino explained in his paper[53], Markov Chains were classified as stochastic processes, which does not have memory; that means the process probability in a given state on the future only depends where it is currently, despising its history.

According with Paulo Renato Alves Firmino[53], a Markov Chain was irreducible if there was, at least, one likely path between all pairs of nodes and called aperiodic if the probability to remain in any of their states in an immediately following transition was not null.

In Takuya Murakita et. al[54] paper, they used Markov Chain Monte Carlo method to track a person walking in the house. They used two prediction models: a generic linear model (Gaussian model) and a highly nonlinear model (Bipedal model). With their experience, they concluded, both of the models can track easily a person in the house, with an error of 58 cm. The Gaussian model required much less computation and the Bipedal model discriminated people more finely (figure 3.17). They also explained that the Gaussian model was good to apply in tracking a number of people and the Bipedal model was better when the accurate tracking was required.

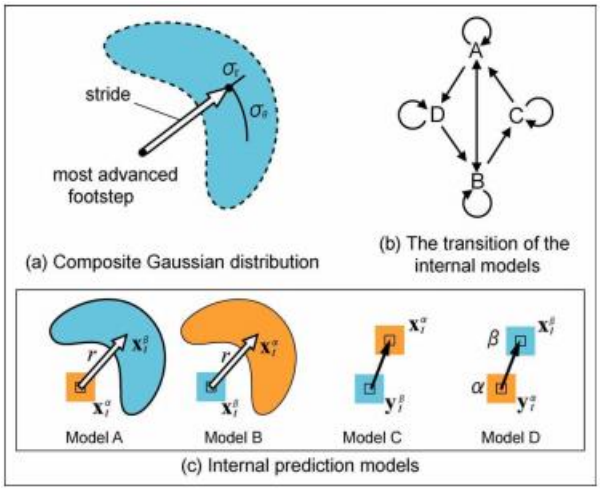

Figure 3.17 - Bipedal model [54]

In case of elderly people living by themselves, the Bipedal model was the best to be used, because was important to track the inhabitant with the most precision possible.

The system they used (check the paper[54] for more detail information), had some sensors which were insulated by thick carpets. They had a problem with the binary sensor sensitivity because would be a lot of people walking there, which in the case of only one person would be much easier.

In the paper[54], they considered the human walking as a Markov process since the position at a time step strongly depended on the position just before the time step rather than on many past positions; was considered the Markov Chain Monte Carlo method (MCMC) the best tracking algorithm for those kinds of signals. One of the advantages of the MCMC was when some information has been lost and no particles hit their prediction, the particles were re-sampled assuming an observation of uniform distribution.

According to the paper, MCMC was very resistant to signal loss, which makes it suitable for tracking people with simplified floor sensors.

After they modeled the prediction model using two different ways, they did four experiments to examine the effectiveness of floor sensors and the MCMC. First, was tracking accuracy vs. walking speeds (figure 3.18) and then tracking accuracy and number of particles (figure 3.19).

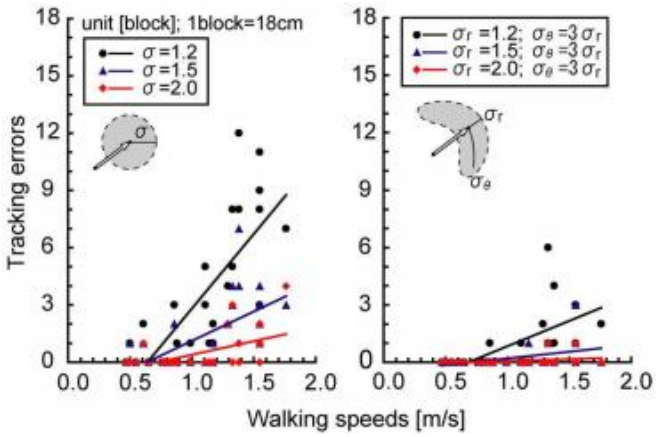

Figure 3.18 - Tracking errors vs. walking speeds [54]

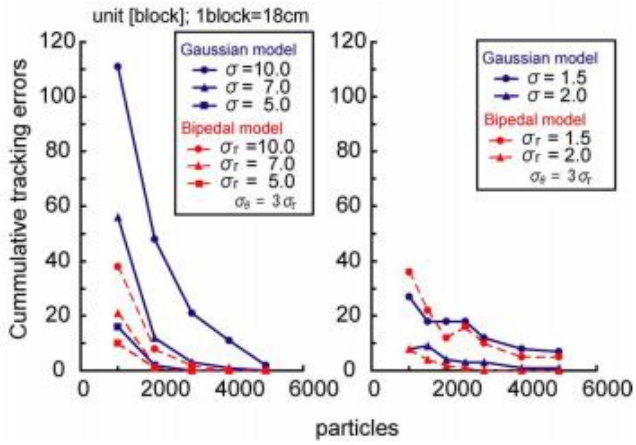

Figure 3.19 - Tracking accuracy vs. number of particles [54]

In their first experience they used 10 people and then they did another one only using 2. While one was stopped the other one was walking (figure 3.20).

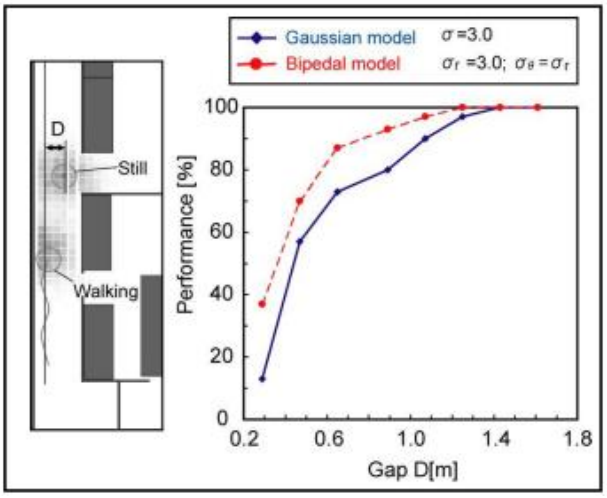

Figure 3.20 - Experiment with 2 participants [54]

Based on their results, they concluded, for every interval smaller than 1,4 m, the bipedal model discriminated more effectively than the Gaussian model. They also concluded the system can perfectly track a person who walks alone.

As Pau-Choo Chung and Chin-De Liu[28] explained in their report, they used a Markov model in order to understand the human behavior in a nursing center.

To extract an activity from video stream was necessary to detect the foreground objects and extract image features. To detect foreground objects was used the background model which involved subtracting with threshold to determine foreground pixels.

As they mentioned, a human behavior is composed by three components: surrounding environment, human activities and temporal information. There was a risk that the same activity represented entirely different behavior under different context. As example, the activity “walking” with spatial context sequence “door, sidewalk, bed” and “bed, sidewalk, toilet”. The former behavior could be “a person goes to bed” and the later behavior could be “a person goes to toilet”, like they explained in the paper. Was important to consider the context because plays an important role in behavior understanding.

Was necessary to consider the spatial context such as location and equipment interaction; temporal context such as time and duration.

In the paper[28], was analyzed the Hierarchical Context Hidden Markov Model (HC-HMM), which was devised for taking contexts into behavior understanding (figure 3.21). The HC-HMM 3 components: spatial context reasoning (SCR) module, the behavior reasoning (BR) module, and temporal context reasoning (TCR) module (figure 3.22). For more detail is advisable to consult the paper[28].

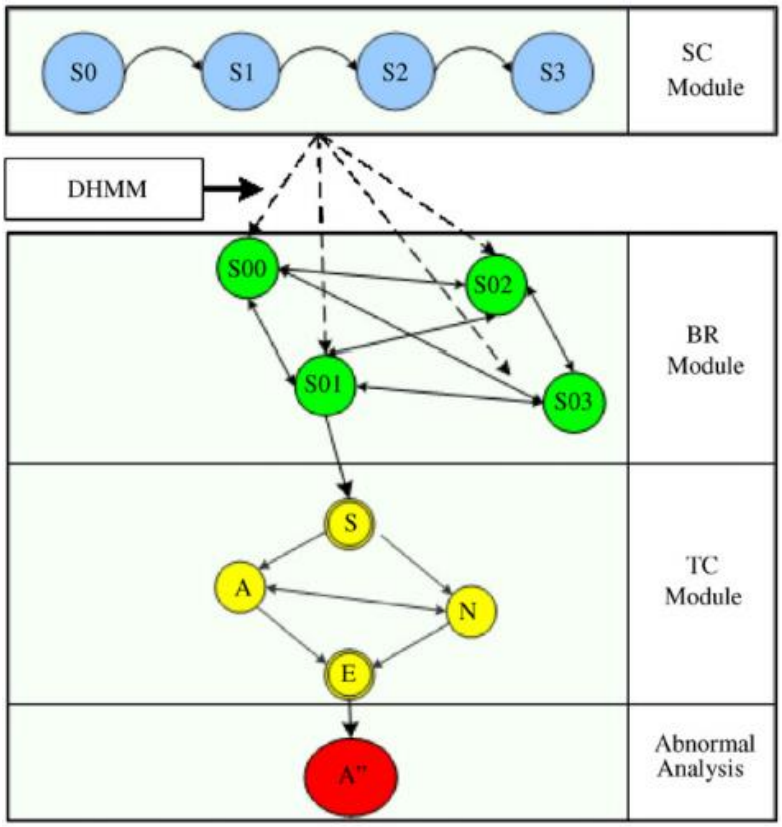

Figure 3.21 - The architecture of the daily behavior enabled HC-HMM [28]

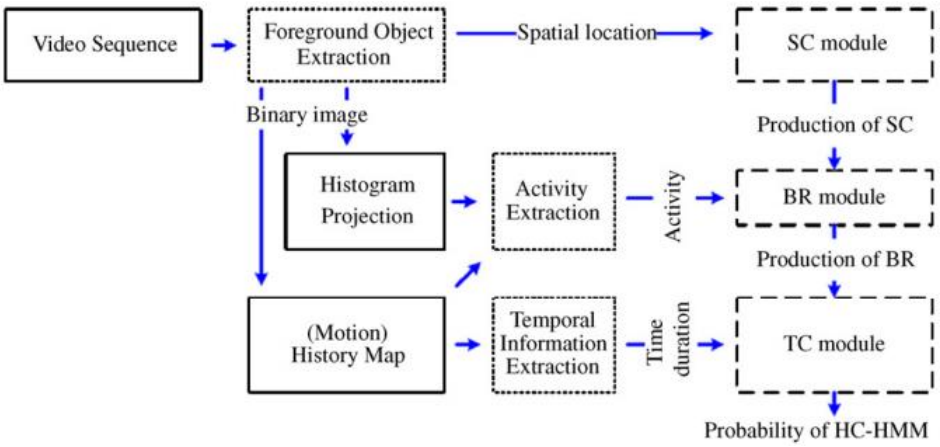

Figure 3.22 - The implementation step diagram [28]

According to the paper[28], different people may had different activity speeds. An activity can be represented by a sequence of postures and motions with orders.

The activity recognition was determined through the maximization of the observation probability of activity models under the prior knowledge constraints of key postures and motion orders for each activity, like was explained in the paper[28].

The purpose of behavior reasoning was to inference human behavior with a sequence of activities under spatial context. For more specific information, is advisable to consult the paper[28].

The study was important, because they studied not only postures and activities, but also took into consideration, the activities and context of them. They had really good results with 85% of accuracy rate.

According to Anne S. Hsu et. al paper[55], they presented a method to identify people using categories. The method had previously been built by using Markov Chain Monte Carlo algorithms and had the basis for designing behavioral experiments, which they called discrete Markov Chain Monte Carlo with People (d-MCMCP).

The method was to estimating the structure of categories using an arbitrary discrete set of stimuli, making it possible to investigate real life categories using complex stimuli, such as images from online databases.

To estimate these categories, the Markov Chain Monte Carlo with People (MCMCP) method had been applied, using parameterized face stimuli.

As first experiment, they examined the categories of “happy” and “sad” faces using a database of images of real faces. By using the same image database allowed direct comparison between the results of d-MCMCP and MCMCP. They concluded the d-MCMCP produced comparable or better performance to MCMCP when applied to a set of stimuli where both methods could be used.

For their second experiment, they used the d-MCMCP in order to explore categories of images associated with the seasons Spring, Summer, Autumn, and Winter. Those images were obtained from online image databases.

They presented a new method for estimating the structure of people's mental representation using categories, which was comparable to existing methods; but by extending the MCMCP algorithm it can be applied to any arbitrary set of stimuli. The d-MCMCP method created the possibility to measure people's representations of a broader range of natural categories and in a greater variety of real world settings.

For more detail, is advisable to consult the paper[55].

Chapter 4

Selection of the best methods to use

In this chapter it is made the comparison between the different ways to store information, Communication Protocols and methods to infer a person activities and behaviors.

4 Selection of the best methods to use

The experimental part consisted of building a model based on the inhabitant behavior, using the best storage method, the best protocol that allows all the sensors and actuators to communicate with each other and the best method to infer with the inhabitant activities or behavior.

4.1 Way to store information

As long I was doing the research in order to find the different ways to store information, I noticed it was complicated to gather information about the way data has being store; or just by saying it was used an online database without more detail information about that, or just by simply saying it was used some information to accomplish the experience.

By these facts, I thought would be important to figure out, for this specific case, the best way to store information. Between the possibility to use a Database or Text Files to store the information collected from the sensors and cameras, was key to find the best way and easy way to do it.

The use of the Database could easily be seen as the best way to do it, is possible to store big amount of information in tables, easy to access (for example, if someone want to see what the inhabitant was doing 2 weeks before, at a specific day and time) just need to do a query (a request for information from a Database) for that day and hour he or she wants and immediately gets the information (figure 4.1 shows an example how it works a query to a Database); but the Database method is also a more complex system, when compare with Text Files.

Figure 4.1 – Query to a Database [56]

For this model, to be used just by the inhabitant in his or her house, by authorities and eventually family, is a small system, doesn't need anything big and complex. Since the model to be implement in the house is with the purpose of helping who lives there alone, to help with daily routines (turn on or off lights, warning about doors or windows open or close) and to have the possibility to send a warning to authorities and family when something is happening, for example lying in the kitchen's floor, which is not a normal thing to do; or get up in the middle of the night and go to the balcony or leave the house, which could represent the beginning of dementia problems.
And since the Database is better to be used with big companies, where there is the need to store a lot of information and easier to access, in these situation the information to be stored is not so much.

Facing these facts and the fact that is not that important for these case, to have the possibility to look for information some days before and because is an easier way to do it, the best option to store information collected from sensors and cameras, in this case, is the Text Files method, CSV Files.

4.2 Communication Protocol

After deciding the way to store information was also important to choose the best Protocol to use. Since the model to be implemented in a house, is going to have sensors, when is used an automation system with sensors is important to have a good communication with all of them, in order to avoid “misunderstandings”.
Was decided the best Protocol to be use is TCP / IP. The TCP / IP allows the connection between no similar systems, allows and enables older technologies and new to connect to the Internet and since is a method that works using layers, also allows the connection between 2 distant points.
But the decision key to use the TCP / IP Protocol came directly from the Norwegian Health Directorate[12], since they want to implement in Norway until the end of 2018 a change in the communication platform from analogic to digital.

4.3 Method to infer with the inhabitant activities or behaviors

Since there was a definition with the method to use to store information and with the Protocol to have the communication between all the automation systems in the house, was missing the method to infer with the inhabitant activities or behaviors.

Since the beginning was decided to study three methods that could be used in this model, Fuzzy Logic, Neural Network and Markov methods.

Despite the fact I thought the Fuzzy Logic would not be a good option, was possible to find some information about its use in this kind of models. The Fuzzy Logic works with rules and intervals where the action will occur. Facing this problem, was definitely not a good option to use in this study; the inhabitant while is in the house, is possible to do a lot of different things and decide to do something in a couple of seconds, and for each movement the system would need to have a rule for that already.

With this, the use of Fuzzy Logic to implement the model in the house was no longer an option.

After analyzing the Fuzzy Logic method was analyzed the Neural Network method, which seemed to be a good option.
By using the Neural Network method was not necessary to use rules to describe each behavior, was just necessary to train the data collected in order the system to know what possibly could do the inhabitant, see how accurate the system could be after the train and if was accurate, use that data and build the model.
In order to have a better and more accurate system, is needed to use as much data is possible. For example, to predict one week, if is used data collected from 2 months will have a result, but if is used from 4 months, will be even more accurate.
But after analyzing this method and see how was possible to use in the house, proceeded to the analysis of Markov method.

The Markov method was a new method for me, but with more information was reading about it, was starting to think it was a good way to use to build the model.
As a model based in probabilities was perfect to be used, because for example, if the inhabitant is in the room he has a few probabilities for what to do next, walking to the kitchen, to the bathroom, to the living room, go to the bed, or simply do nothing. By using this method is built a decision tree which gives the probability for the next step the inhabitant will give. For the system to give the probability of his or her next move, the system only needs the exact previous move he or she did, not depending what he or she did few hours before or some days before.
By using the Markov Chain Monte Carlo avoids the use of a lot of data to study the inhabitant behavior, just the previous move to “guess” what is supposed to do next. With this method is also easier to warning authorities and family when a problem occurs, because if the inhabitant is laying down on the floor, based on the probability that he or she supposed to do next, the system will notice that action had the lowest probability to happen, noticing something wrong just happened.

With the analysis of the 3 different methods, a good method to use was by far the Markov Chain Monte Carlo.

Chapter 5

Simulation

In this chapter it is presented the simulation by using the methods considered in the chapter 4.

5 Simulation

As being concluded on the point 4, a good method to be used was the Markov Chain Monte Carlo.

In order to start the simulation part was important to create some data as an example as a daily routine for the inhabitant, hours to wake up, time to go to the bathroom, to the kitchen, how long is normal to stay in the bathroom, how long he or she takes in the kitchen, if is standing or siting eating; trying to create as much accurate as possible to a normal routine.

The goal was to use Matlab, as programming tool, to build the model that described the inhabitant behavior in the house.

After “creating” a day as a routine, was expecting to use that information as starting point and use it in the Workspace in Matlab to create the rest of the data for how many days I wished.

All the data created after “running” the code wrote in Workspace, would be saved as CSV Files, which would put each row for a day. Would be possible to see, for example, in the first row, the time, following by the behavior at that time (6h13 wake up), next other set of time and its behavior (6h17 walks to the bathroom).

All the data would be separated by commas, as a CSV File is; would be: time1, behavior1, time2, behavior2, time3, behavior3, time4, behavior4…

Since the method to be used was decided to be Markov Chain Monte Carlo, for the system would just matter the previous behavior. For the system to know what would be the probability to go to “time4” for the “behavior4” would just matter what the inhabitant was doing in the “behavior3” at “time3”, would not matter the “behavior2” at “time2”.

After building the model using Matlab, would be possible to compare with a decision tree (previously built), with each probability for every behavior and see if the model built using Matlab was accurate enough.

Like was referred in the preface section, the problems with the programming part, came to confirm. Had some problems with programming and to try to get decent data to use it to build the model.

Even after some tries was remarkable the problems with getting data, because of that and the lack of time to conclude the work, decided to drop the Markov Chain Monte Carlo method and tried to use the Neural Network method, which was one I knew a bit more.

For the use of Neural Network method, was created a CSV File with data for 61 days (June and July of 2015).

All the inhabitant's behaviors for the 61 days were completely different and independent from each other, without repeating any day.

Each row represented each day (1st June until 30th June and then 1st July until 31st July).

Each column was the schedule for 24 hours. Every hour was divided in 12 parts, 5 in 5 minutes, in order to use the same interval of time for every day.

Every day started at 00h00 and ended at 23h55.

In the table 5.1 there is an example how the information was represented.

Table 5.1 - Example of the file created

	00:00:00	00:05:00	00:10:00		06:50:00	06:55:00		23:50:00	23:55:00
03.06.15	2	2	2		5	10		2	2
04.06.15	2	2	2		5	5		2	2
…	**…**	**…**	**…**		**…**	**…**		**…**	**…**
12.07.15	12	12	12		2	2		2	2
…	**…**	**…**	**…**		**…**	**…**		**…**	**…**
24.07.15	2	2	2		5	6		12	12

Every behavior was a code, to be able to use the file as a matrix file in the Matlab (table 5.2).

Table 5.2 - Example of the codes used

Codes	Activities
2	Habitant is in the bed sleeping
5	Habitant is in the bathroom
6	Habitant is walking from the bathroom to the kitchen
10	Habitant is walking from the bathroom to the bedroom
12	Habitant is out of the house

The file was a matrix 61x288, which was divided in 2 files to proceed with the simulation part using the Neural Network toolbox in Matlab. The toolbox used was “nftool”.

By using the toolbox “nftool” was necessary to define an input and a target.

As input was use all the data as a matrix, except the last row, which corresponded to the 31st July, creating a matrix 60x288. As a target was use the data as a matrix from 31st July creating a matrix 1x288 (figure 5.1).

To select the percentages, was decided to choose:

- Training 90% which corresponded to 260 samples
- Validation 5% which corresponded to 14 samples
- Testing 5% which corresponded to 14 samples

The number of hidden neurons was decided to be 20.

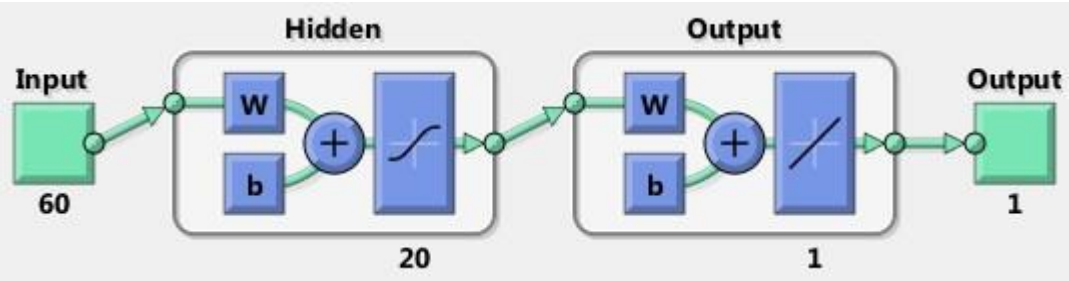

Figure 5.1 - Neural Network diagram

The purpose of using this toolbox was to see if the system, based on a data from 60 days, could predict the 31st July.

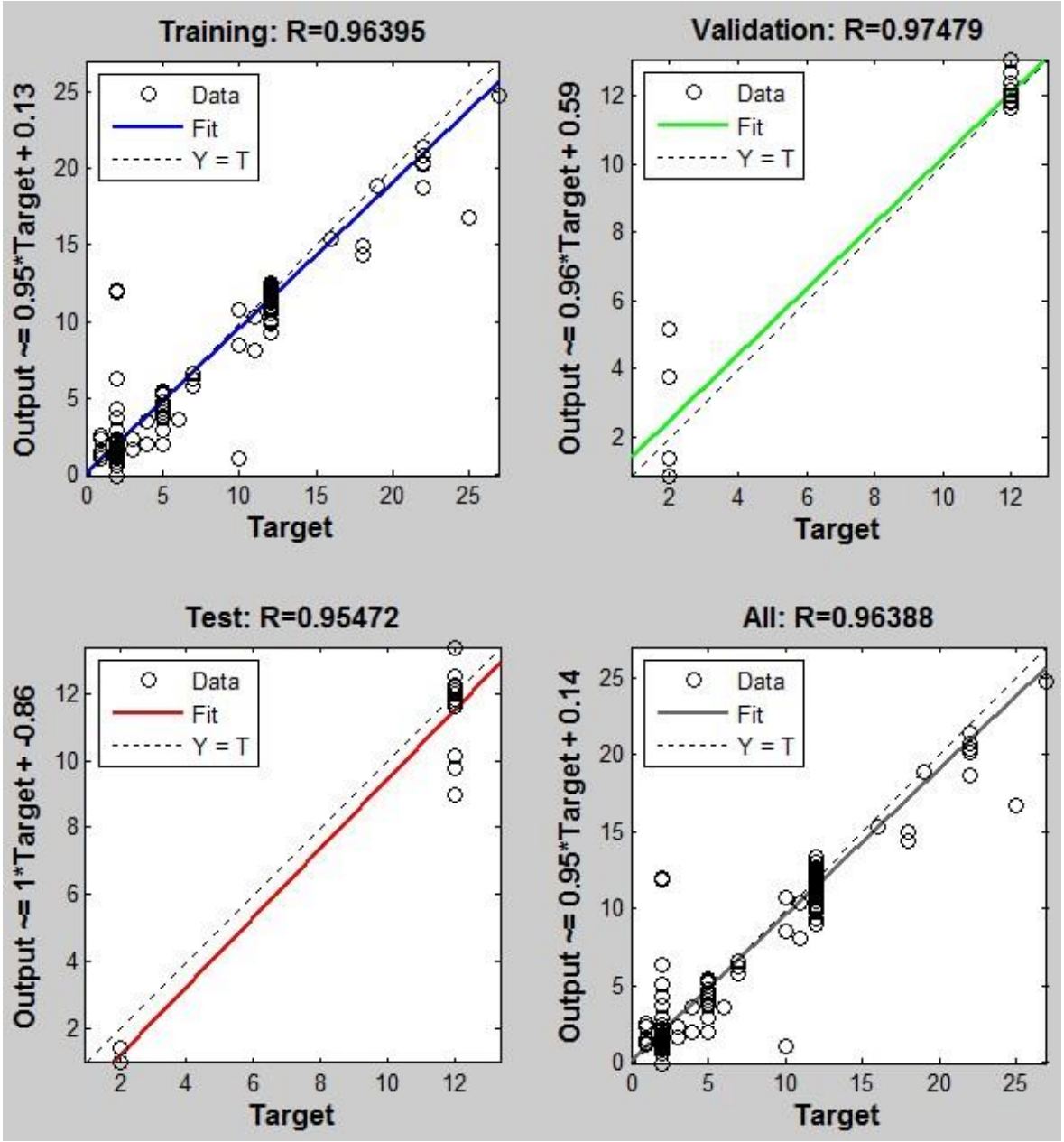

Figure 5.2 - Graphics results after train the network

Analyzing the figure 5.2 is possible to see that the system was really accurate to predict the 31st July.

By changing some parameters in the toolbox is possible to get results completely different from the ones got with the training. To make sure that the system will be more accurate, is possible to "force" that using more data, instead of 61 days maybe use 100 days or even an entire year.

After validating the data, the next step was “removing” the data that was been processed by “nftool” and build the model for the house, by using it as input and without a target, try to give an output, the prediction of some days.

Once again the programming problems prevailed and because the lack of time to try to solve the problem and build the model, unfortunately was impossible to use the data process by “nftool”.

By the end of the programming part, because of the programming problems and the lack of time to solve the problems, was clearly obvious that the Neural Network method was not the best to use to build the model to be used in the house.

For example, looking to the simulation that was conducted, the purpose was to predict the next day with data collected from previous days, which was a success; but analyzing that information, is possible to understand is no good to be used as a perfect model. The model will always have a 1 day lag.

Let’s imagine, in the morning something happen with the inhabitant and he or she fell down in the kitchen and by this model only on the next morning the system will detect the problem. The system could not detect the problem when actually happen or even worst, could assume that as part of the routine.

Chapter 6

Discussion

In this chapter it is presented a discussion over the work with prospects of progressing, chances of future work.

6 Discussion

As documented in chapter 5 occurred some problems with the use of Matlab.

After analyzing all the papers and compared different methods, it becomes clear it would be clever to use this as a way to store information, Text Files (CSV Files) because the amount of information to be stored, however, this does not necessarily exclude Database as another alternative to store information. Rather, it depends on the amount of data that needs storage, and whether access to given information is necessary.

It is possible to choose between various methods to infer with the inhabitant activities or behaviors. As explained in chapter 3, there are advantages and disadvantages to choose the method.

Although the papers pointing the Markov Chain Monte Carlo as a good candidate, it doesn't need huge amount of information to be used and it is more precise, to choose more wisely it is advisable to try all the methods using Matlab. Choose a way to store the data and use with each method and then proceed with the comparison.

For future studies about this topic, it is advisable to try all the different ways, to understand which way more suitable to describe the inhabitant's daily routine and the best way to help the inhabitant when there is a problem.

Chapter 7

Conclusion

In this chapter it is presented the final conclusion.

7 Conclusion

In order to build a system capable to help those who live alone, in a Future Smart House, it was mandatory to “create” a model that could infer with the inhabitant activities and behaviors.

Before locating the best method that will learn the activities and behaviors, it was necessary to find a way to represent and store the information collected from the sensors. Based on the project and the way the information would be used, one good way to represent the data was as CSV files by storing them as a Text File.

It became impossible to do the simulation process to compare 2 methods to understand which one would be more suitable to use in this model. One good method to infer with the inhabitant´s activities and behaviors was by far the Markov Chain Monte Carlo, because of its accuracy, it didn’t need a lot of data and it was based on just the previous activity and behavior, not necessary to know what happened some hours before, so there would be no lag and the system would react immediately in case of some problem happen.

Even though with the problems regarding to the programming and the lack of time, which affected the “creation” of the model for the house, it was possible to conclude, that one good method, more precise and useful is the Markov Chain Monte Carlo and a good way to store the information collected from the sensors is using Text Files, by written that information as CSV files.

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