



Erasmus+

NOVIA
UNIVERSITY OF APPLIED SCIENCES



Project: Healthcare Sensors for the homes of elderly



Care & Connect

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Abstract

The population worldwide is aging rapidly. According to the research, by 2050 the proportion of the population will have reached 65 years and more is expected to peak at 25%. The majority of elderly people live independently, notwithstanding, the decrease of mobility, strength, and reduced sensory cognition makes it unbearably difficult.

Various support systems are required to preserve independence without influencing the sense of privacy and safety. For the above-mentioned reasons, smart homes utilizing various sensors are being developed nowadays. In the project described further in this report, the emphasis was put on implementing and interconnecting the following sensors: pressure, air quality (gas and humidity), motion, temperature, light, and flame. Performance of sensors was examined in a specially designed room being a simulation of an apartment. Moreover, proper marketing strategy was invented to educate future healthcare workers and nurses about the possibilities the sensors' technology brings.

To sum up, the network of sensors was created and installed in the simulation room. What is more, different marketing approaches were taken to educate future caregivers and nurses.

Keywords: sensors, IoT, elderly people, healthcare

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1. The EPS Project

The European Project Semester (EPS) is a program offered by nineteen European universities. The goal of this program is to prepare students in engineering for their future tasks and challenges but also to teach them how to manage a project. All the EPS is held in English. Plural projects are offered at the start and each candidate makes a wish for the one that tempts them the most or the one that is closest to their study environment. Indeed, not everyone comes from the same field of study with very different and complementary backgrounds. While some study electronics, others study mechanics, chemistry etc.

It is also a very good way to be immersed in a multicultural environment, especially with our world developing more and more of a society based on exchange between countries. It is therefore important to know how to communicate with others and understand their way of working.

The projects are assigned depending on the field of study and also on the nationality of the student. The project starts in groups of 3 to 6 students and contains at least three different nationalities to have a multicultural environment

We have courses around our project that allow us to better structure it and learn to better manage it such as Team Building courses or English courses for engineers. But it is also possible to enrol for complementary courses like in our case.

Five projects were proposed:

- 3D Printing tool for industrial robot
- Adiabatic Compressed Air Energy Storage
- Classification of sounds
- Healthcare Sensors
- IoT for small factories needs

We have been assigned to "Healthcare Sensors" and our tutors are Mikael Ehres, Linda Jönn and Viveka Öling-Wärnå.

To best meet the expectations of the project we had the opportunity to enrol in two additional courses such as a "Basics in Internet of Things" course to help us understand and program our sensors but also a 3D printing training.

2. NOVIA University of Applied Sciences (UAS) in Vaasa

Nowadays NOVIA counts about 4000 students in 5 cities in Finland. It is also the biggest Swedish-speaking University of Applied Sciences in Finland. For NOVIA, it is important to “develop a working life and industry near-by the campuses” and to build a “strong network of partner institutions in order to promote mobility and create opportunities” as we can read on their website. This is also why the university is able to propose advanced and interesting projects to students in EPS.

Technobothnia

It is a big building co-owned by multiple universities such as Vaasa University of Applied Sciences, University of Vaasa and **Novia University of Applied Sciences**.

You can find in multiple laboratories and places which are divided into different parts as:

- Construction and Engineering
- Energy Technology
- Physics Laboratory
- Environmental Technology
- Computer Aided Engineering & Quality Control
- Material Technology
- CAM and CNC Technology
- Digital Manufacturing
- Mechanical Engineering
- Automation Assembly / Robotica
- Computer Engineering
- Automation Technology
- Telecommunication Engineering
- Electrical Power Generation, Transmission and Distribution
- Electrical Engineering
- Electrical Research

All these spaces have been designed for research but also for student projects. The latter can find a large quantity of material, machines but also advice from qualified teachers. It provides students with access to a very rich and interesting education. All this building has been thought in order to ensure and perpetuate the fact that the region has a major place in the technology hubs in Finland¹.

Indeed, many projects have companies as partners, which gives a whole new dimension to the project. Thanks to the subsidies of these companies, the projects have more budget and the students have more resources to go further technically with their projects. Nevertheless, there are not only laboratories but also meeting rooms and workrooms that allow students to organize project meetings and work together on non-technical tasks.

In our case, a room was assigned to us so we could have a place to work. Indeed, the simulation room, our subject of study, is not located in the Technobothnia building. So, we needed a place to meet and work together.

¹ <https://www.technobothnia.fi>

3. Introduction of the team

Our team is multicultural, we are 6 students from 4 different countries. The project is therefore designed and developed with a Belgian, Polish, German and French mindset.

We are also in connection with another student named Eva Barceló Michans (Spain) who is working on the same project with whom we can exchange our difficulties and ideas.

This difference is a real wealth because it allows us to exchange between us on the differences within our country with regard to the subject. Moreover, we also have the Finnish point of view thanks to our tutors.

Stijn Peeters

Country: Belgium

Age: 21

Home school: Thomas More Geel

Studies: Energy technology



Hi! My name is Stijn Peeters and I come from lovely Belgium. I live in the Dutch speaking part of Belgium in a town called Kasterlee. I study at Thomas More in Geel, the field of study I follow is energy technology where I learn everything about renewable energy.

Ever since I was young, I said that I wanted to work abroad later. That is one of the reasons why I chose to do an internship abroad. I have also signed up for EPS so that I can improve my English. The last reason I came here was because I like to get to know new people of different nationalities to see how they think and live.

Figure 1: Picture of Stijn Peeters

Jim Van den Troost

Country: Belgium

Age: 22

Home school: AP Hogeschool

Studies: Graphic and Digital Media



Hi, I'm Jim and I'm from brave little Belgium and live in a little city called Malderen. I'm currently studying Graphic design at AP Hogeschool in Antwerp and more specifically, I'm studying Graphic Media Technology which means I learn to create designs for printable materials.

I hope to acquire more team building skills via this EPS project. The international aspect intrigues me but it's also a challenge due to the fact of different cultures but also different fields of studies. In the end I'm already happy to be here and experience the winter wonderland of Finland!

Figure 2: Picture of Jim Van den Troost

Julia Nowakowska

Country: Poland

Age: 22

Home school: Technical University of Lodz

Studies: nanotechnology



Figure 3: Picture of Julia Nowakowska

Hi! I am Julia and I come from Central Poland, a city called Łódź. I have been living there almost my entire life. I study at the Technical University of Lodz, to be more exact at the International Faculty of Engineering. My field of study considers chemistry and physics, and we learn how to develop new technologies in nanoscale. It has always been my life-long ambition to become a scientist and I do believe that taking part in this EPS program sets me closer to my goal.

But I wanted to participate in this exchange not only because I want to learn more, but also because I love getting to know other cultures, countries and most importantly - people. I am really happy to be in this EPS program and I do believe it is a very precious experience.

Ege Kerem Bektemur

Country: Germany

Age: 21

Home school: Fachhochschule Kiel

Studies: Electrical engineering



Figure 4: Picture of Ege Kerem Bektemur

Moin, as you would greet others in my hometown! My name is Ege Kerem and I am from Kiel in northern Germany. Currently I am studying electrical engineering at 6. semester at the Fachhochschule Kiel. I specialized in energy technology which handles different aspects of high voltage work and generators.

I applied for the EPS because I wanted to set myself new challenges during my studies and improve my English. In addition, working in an international team with different fields of study is an experience where you can gain new knowledge from each other and improve yourself. I think that solving a real problem is more engineering than just the blank theory.

Marina Duclos

Country: France

Age: 20

Home school: ENIT

Studies: General Engineering



Figure 5: Picture of Marina Duclos

Hey ! I am Marina Duclos, I live in the Southwest of France, completely on the bottom left side of the map. I am learning about general engineering, which means a little bit of mechanics, materials science, electricity, industrial engineering, etc. My personal preferences are industrial engineering because most problems we need to solve look like a puzzle to me and designing pieces on CAD software's.

I chose to do an EPS because I love working in groups, and I think a concrete project experience will be much more enriching than a traditional semester abroad with only lectures.

Laetitia Chopard

Country: France

Age: 23

Home school: Université de Reims Champagne-Ardenne

Studies: engineering school in Packaging



Figure 6: Picture of Laetitia Chopard

I am Laetitia and I'm from France. I am studying packaging which means the art of packing things: I deal with technical points as well as the whole process of creation, traceability, marketing, price study etc...

I wanted to take part in the EPS project proposed by my school because I wanted to discover a new country, a new culture but especially to discover and exchange with people who come from all over Europe. My goal is to improve my English level but also to learn to work with people from all over the world.

I also think the EPS project is a good way to become more versatile in subjects that are not our own and to learn from others. It's very rewarding. I like the challenge and I am very happy to be in Vaasa to take part in the EPS program.

Team leader and secretary

In the first part of the project Jim was the team leader. He was responsible for keeping an overview of the project's progress and the agenda for the meetings, highlighting issues to be discussed during next meetings, and monitoring each member of the group during the first half of the project. He was also in charge of facilitating and managing our meetings, both with our tutor and among ourselves.

Julia was the secretary. She was writing so-called "minutes" notes from the course of each of our meetings. Minutes written by her included discussed points, questions/doubts and the track of the progress, changes, and tasks as the project was being further developed.

On the second part of the project Julia was still the secretary and Kerem had taken the role of team leader.

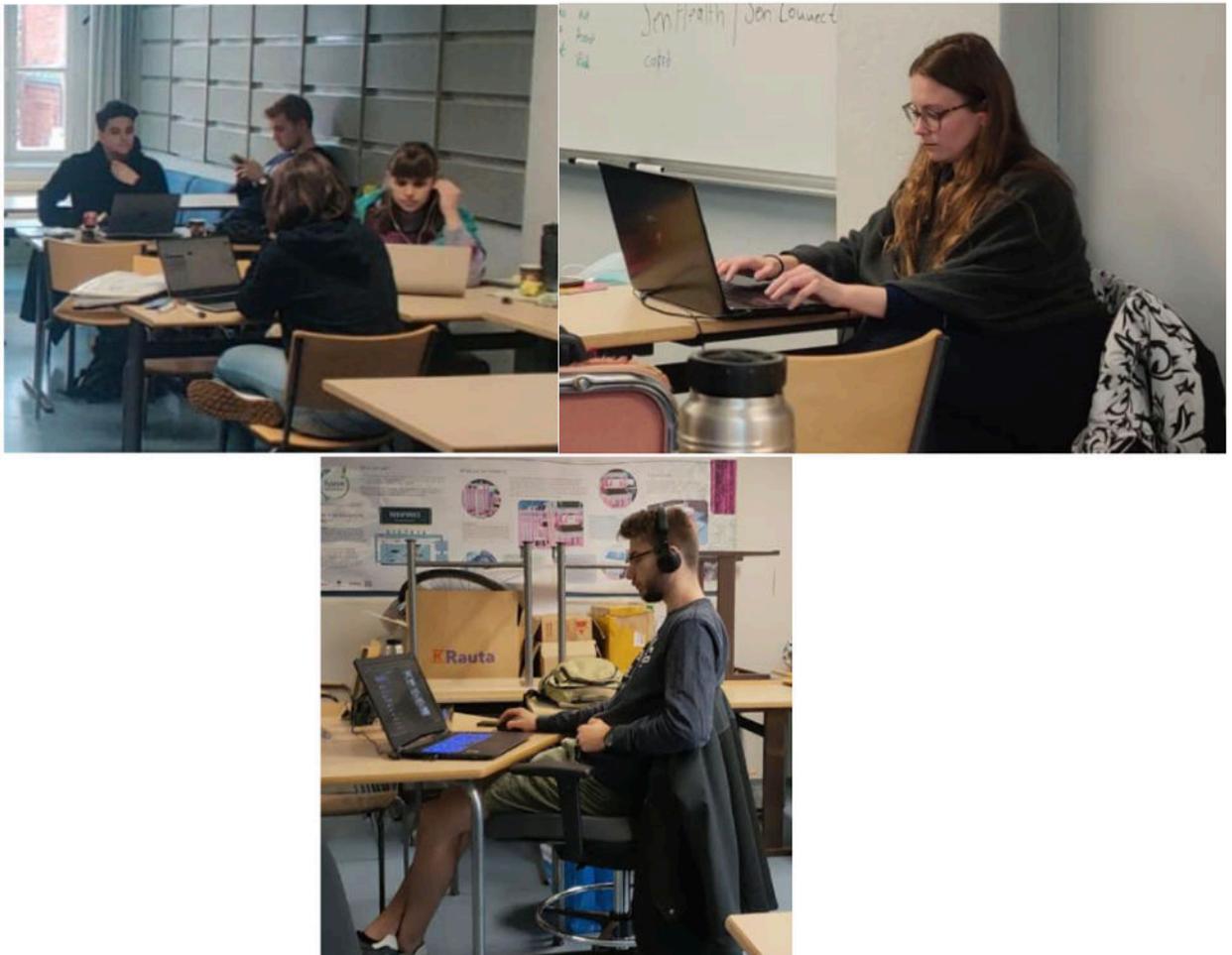


Figure 7: Group working at Technobothnia

4. Defining our project

4.1 Vision

The subject of our project is to create a network of multiple sensors that recognizes accidents and prevents further injuries by informing responsible people. By creating such a system, a lot of subsequent injuries can be prevented, lives can be saved, and a sense of security can be restored. The real-time data can be reviewed via an app or a website by healthcare workers or family members of a user. Furthermore, we have an educational mission by showing other people what is possible with the help of sensors.

4.2 Mission

We are the first group to start working on the development of a healthcare and accident prevention system (using interconnected sensors) for elderly and disabled people. The simulation room in the Alere building, also known as the clinical trainings center, was finished in autumn last year. It was created for the future medical workers to learn and improve their skills but also get hands-on experience. Therefore, it is very important to build for the future and allow next generations of EPS students to continue our work and improve it. Implementing new digital solutions with the help of sensors will initiate students about welfare technology solutions.

4.3 Objective

The objective of the project is to create a network of sensors that can be potentially located in the homes of elderly people. The creation of the network is only one of the issues in the project. The emphasis is also put on the design of packaging to hide the sensors and on the marketing of the technology to the target group - nursing students who are potential buyers in the future.

5. Simulation room

5.1 Definition

The healthcare room is located in the Alere building near Technobothnia. The Alere is a clinical testing center for future nurses and medical staff. The simulation room is normally used for teachers and students to rehearse scenes and analyse students' behaviour using the built-in cameras. Due to more advanced technology in the healthcare sector the goal is that students also learn how to operate with new systems.

Our room is located in room A268 on the second floor. Underneath is a map with the different rooms and how to find our room.



Figure 8: Plan of the Alere building

5.2 Presentation of the room

The simulation room that was realized is composed as follows:

In the first place we have:

- a relatively low bed for an elderly person
- a bedside table
- many plugs



Figure 9: Simulation room (1)

The kitchen is equipped with:

- a fridge
- a sink
- several cupboards on top
- two electric cooking plates
- a paper towel dispenser
- few plugs



Figure 10: Simulation room (2)

In between the kitchen and the bedroom are:

- a table
- two chairs
- few plugs



Figure 13: Simulation room (3)



Figure 11: Simulation room (4)



Figure 12: Simulation room (5)



Figure 14: Simulation room (6)

Finally, there is a living room area with two armchairs, a sideboard, a large lamp, a television, a table, a rug, a chair and a few decorations and plugs.

Unfortunately, we don't have a bathroom, which is considered one of the most dangerous rooms in a house, especially for the elderly. The whole room is equipped with multiple outlets and there are big windows.

This is only a global representation of the rooms of elderly people. It should be taken into consideration that there are almost as many configurations as there are people. The goal is to be able to propose a general solution that can be adapted to all situations.

5.3 Opportunities

The health care room at Novia has a lot of opportunities in regards to using sensors. In general, there are already two existing cameras which are used by the nursing school for educational purposes. In the following we will show examples of what possibilities are available to integrate. However, we need to know what sensors we will be able to put in place before we can define where to put them.

Nevertheless, one of the main ideas is to hide them so that they are not intrusive in the life of the elderly. Indeed, many people are still reluctant to technology and even more to connected systems. It is therefore important to make them as discreet as possible.



Figure 16: Possible Sensors (1)

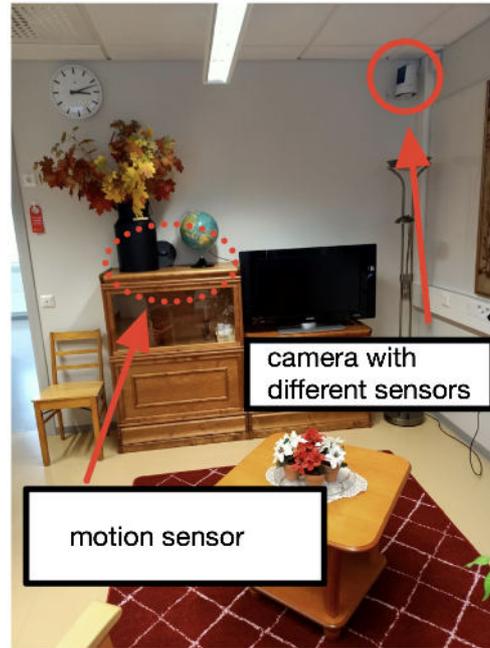


Figure 15: Possible Sensors (2)



medical dispenser

Figure 19: Possible Sensors (3)



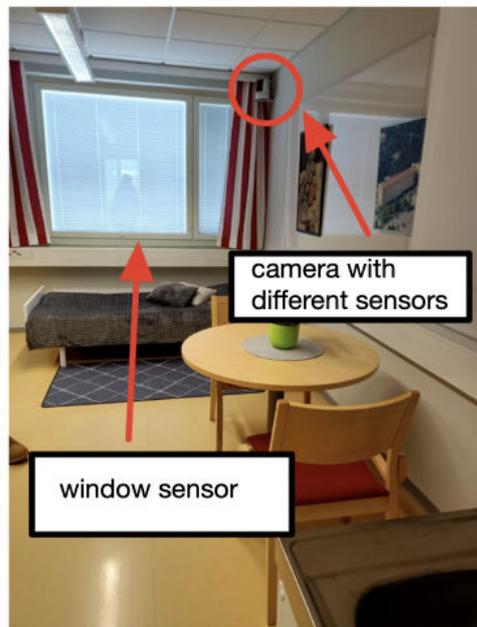
waterflow and humidity sensor

Figure 20: Possible Sensors (4)



pressure sensors

Figure 18: Possible Sensors (5)



camera with
different sensors

window sensor

Figure 17: Possible Sensors (6)

6. Research

6.1 Definition of Sensors

Sensors can be defined² as devices that transform chemical, physical, and biological information into analytically useful information. A sensor is a device that receives a signal or stimulus and response to the stimulus in the form of an electrical signal. The output signals correspond to some forms of electrical signal, such as current or voltage. The output signal of a sensor may be in the form of voltage, current, or charge. Sensors may be divided into two main groups: passive and active. In general, active sensors require an external power supply in order to operate and this supply is very often called an “excitation signal” which is crucial for the sensor. This allows them to produce output signals. Active sensors are self-generating devices. On the other hand, there are sensors that do not require any additional power source or excitation voltage. These are the passive sensors. This type of sensor responds to an external stimulus with an output signal.

Sensors are characterized³ depending on the value of some of the parameters. Important characteristics of sensors and transducers are listed below:

- Input characteristics
- Transfer characteristics
- Output characteristics

Input characteristics may be further divided into:

- Range - the minimal and maximal value of the sensor’s measurement
- Span - the difference between maximal and minimal values of the input
- Accuracy - the difference between the measured value and the true value. It is defined as the % of the full scale or of the reading
- Precision - the closeness among a set of values, it is very often mistaken with accuracy, but those terms are very different. The measurement may be precise but not accurate, i.e. the numerical values may be close to each other (high precision) but deviated from the true value (low accuracy)

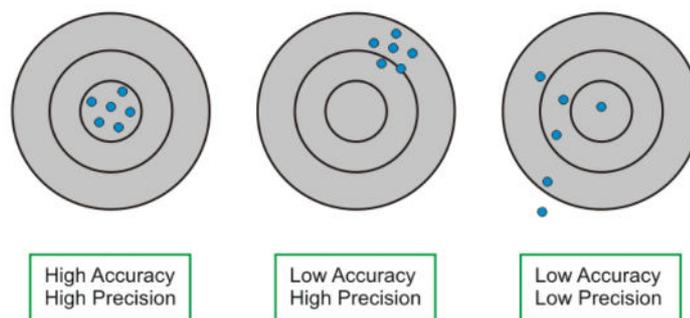


Figure 21: Explanatory illustration of what makes up and defines the precision⁴

- Sensitivity - the ratio of change in output to change in input. Sensitivity may be expressed via following formula:

² Patel, Dr. Bhagwati & Sinha, Professor G & Goel, Naveen. (2020). Introduction to sensors. 10.1088/978-0-7503-2707-7ch1

³ https://www.electronics-tutorials.ws/io/io_1.html

⁴ <https://www.electrical4u.com/characteristics-of-sensors/>

$$S = \frac{\Delta Y}{\Delta X}$$

With following definitions:

S - sensitivity

ΔY - change in output

ΔX - change in input

- Linearity - the maximum deviation between the measured values from the ideal curve. Good depiction of the linearity is presented below:

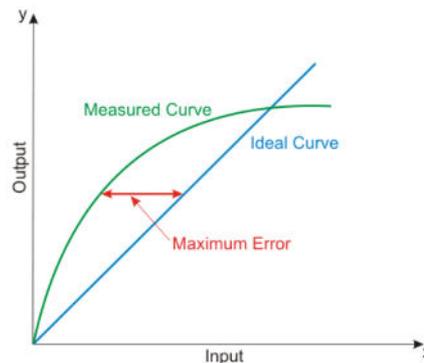


Figure 22: Explanatory illustration of what is linearity⁵

- Hysteresis - the difference between two separate measurements taken at the same point; the first is taken during a series of increasing measurement values, and the other during a series of decreasing measurement values. Hysteresis phenomenon is caused by the reluctance of the material to return to its original state after adding or removing a physical factor causing the change such as, for instance, decrease or increase of the temperature or pressure.

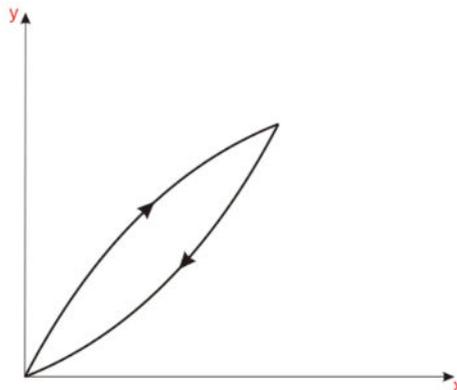


Figure 23: Explanatory illustration of what hysteresis is⁶

- Resolution - the minimal change in input that can be sensed by a sensor
- Reproducibility - the production of the same output at the time when the same input is applied
- Repeatability - the production of the same output every time when the same input is applied and all the physical and measurement conditions kept the same including the operator, instrument, ambient conditions etc.
- Response time - the time at which the output reaches a given percentage of its final value (for example 95%) in response to a step change of input

⁵<https://www.electrical4u.com/characteristics-of-sensors/>

⁶<https://www.electrical4u.com/characteristics-of-sensors/>

- Dynamic range⁷ - the ratio between the smallest and largest possible values of a changeable quantity. Dynamic range is another way of stating the maximum signal-to-noise ratio

6.2 Principal of operation

Generally speaking, sensors are systems possessing a variable number of components. However, three basic units of sensor may be recognized: a sensing element, packaging, and hardware processing a signal. Undoubtedly, additional components to certain sensors exist. The complete “anatomy” of a sensor is depicted below:

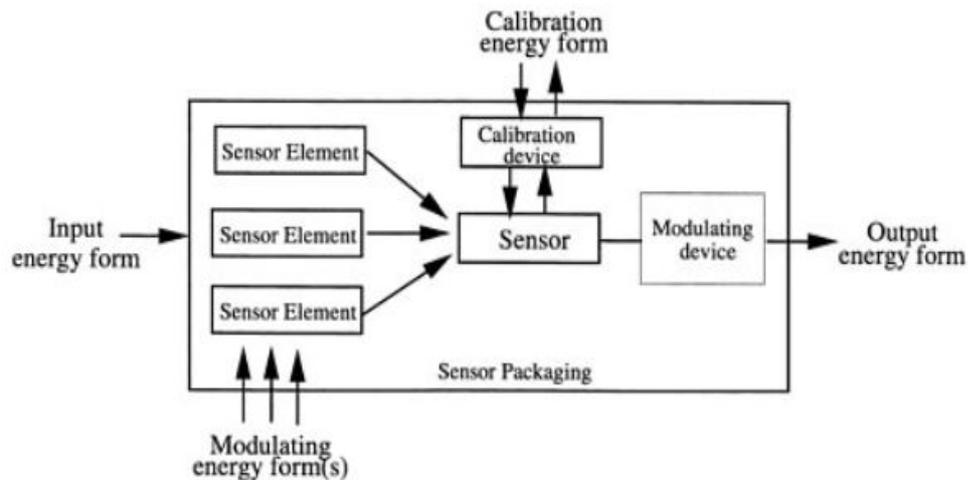


Figure 24: Components of the sensors⁸

As one may observe, a general structure of a sensor consists of 12:

- output “gate”/ interconnection;
- packaging;
- interconnects that modulate input;
- device for calibration;
- input/output calibration;
- device modifying an output signal (so-called amplifier);
- device processing an output signal;
- calibration actuators.

6.3 Classification of sensors⁹

Sensors may be classified on the basis of stimuli they are subjected to or based on their applications.

One may differentiate the following division basing on the stimuli and to changes of which parameter sensors are sensitive:

- **Vision and Imaging Sensors** - ability to sense the presence of objects/colors within the given field of view and convert this information into a visual image
- **Temperature Sensors** - ability to detect changes of thermal parameters. Usually, temperature sensors are based on a resistance temperature detector or thermistor
- **Radiation Sensors** - sensing presence of alpha, beta, and gamma particles

⁷ <http://www.digitizationguidelines.gov/term.php?term=dynamicrange>

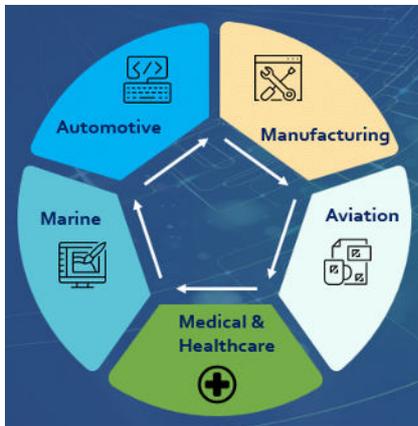
⁸ <https://www.nap.edu/read/4782/chapter/4#11>

⁹ <https://www.thomasnet.com/articles/instruments-controls/sensors/>

- **Proximity Sensors** - detection of the presence of nearby objects through non-contacting means. More often than not, a proximity sensor has a range of detection up to several millimeters
- **Pressure Sensors** - production of output signal on the basis of detection of force per unit area in gases or liquids
- **Position Sensors** - sensing the positions of a given object, for instance, doors, valves etc. and supplying signals to the display devices
- **Photoelectric Sensors** - sensing the movement within their field of operation. However, they are also capable of detecting color, cleanliness, and location. These sensors rely on measuring changes in the light they emit using an emitter and a receiver
- **Particle Sensors** - ability to detect larger airborne particles and supplying information.
- **Motion Sensors** - the movement or stoppage of parts, people, etc. is detected
- **Metal Sensors** - sensing the presence of metal particles under various conditions, for example food packages. Metal detectors can be permanent or portable and they may rely on multiple technologies, but the most popular one is electromagnetics
- **Level Sensors** - electro-mechanical devices usually used to determine the level of gases, liquids, and solids in, for example, tanks or bins
- **Leak Sensors** - detection of the unwanted discharge of liquids or gases. Generally, leak detectors rely on ultrasonic (for air leaking for example), however some sensors rely on foaming agents to measure leakage
- **Humidity Sensors** - measurement of amount of water vapor
- **Gas and Chemical Sensors** - detection of various chemicals and vapors. Gas and chemical sensors/detectors are used for monitoring of a confined space, leak detection, analytical apparatus. They are often designed to detect multiple gases and chemicals
- **Force Sensors** - measurement of force-related parameters such as weight, torque, load, momentum etc. These sensors typically possess a load cell - a piezoelectric device whose resistance is prone to changes when subjected to deforming loads
- **Flow Sensors** - sensing of the flow of vapors, liquids, and solids. A flow sensor can be all electronic using ultrasonic detection or partially mechanical
- **Flaw Sensors** - ability to uncover inconsistencies and various flaws on the surfaces or in underlying materials such as welds. Flaw sensors usually use ultrasonic and acoustic data to identify defects in materials
- **Flame Sensors** - detection of the presence and the quality of fire. These are optoelectronic devices, meaning that they rely strongly on ultraviolet and infrared detection of the flame. They can be used in combustion control devices, like burners.
- **Electrical Sensors** - ability to sense current, voltage etc. Electrical sensors do indeed base upon hall effect detection. These sensors are used whenever information about the electrical state of an electrical system is required, for instance, railway system pumps or heater monitoring.
- **Contact Sensors** - the principle of operation relies strongly on the physical contact between the sensing device and observed object.
- **Non-Contact Sensors** - in this case, as the name implies, in order to detect signal sensors do not require direct contact. A good example of such a sensor may be motion sensors used in security light and surveillance cameras.

6.4 Applications¹⁰

When speaking about fields in which sensors are applied, the number of those have been increasing more and more throughout the years. Sensor and IoT technology can facilitate lives in plenty of different ways.



Main areas in which sensors play a huge role and are a great support are¹¹:

- automotive
- manufacturing
- aviation
- marine
- medical & healthcare
- industrial applications
- aerospace and defense
- agriculture

Figure 25: Graphic of the different areas

However, these are only a few fields in which sensors are commonly utilized. Sensors are commonly used in everyday life. It is not difficult to come into contact with sensors continuously, for instance, a kettle uses temperature sensors to reach the appropriate temperature, a coffee machine uses pressure sensors to monitor the amount of liquid that is being dispensed. The examples of home appliances with sensors are: a heating system boiler, washing machines and dishwashers.

Sensors can improve the world through diagnostics in medical applications; improved performance of energy sources like fuel cells and batteries and solar power; improved health and safety and security for people; sensors for exploring space and the known universe; and improved environmental monitoring.

6.5 Sensors

6.5.1 Carbon monoxide sensor

Why?¹²

Carbon monoxide also known as CO is a life-threatening gas that is produced by incomplete combustion of natural gas, wood, petrol etc. The reason why it is so dangerous is because one cannot smell, taste or see it. That is why it is also called the silent killer. Carbon monoxide is absorbed into the blood 250 times faster than oxygen. A small amount of carbon monoxide in the air can quickly lead to unconsciousness and even death if prompt action is not taken.

¹⁰ <https://www.variohm.com/news-media/technical-blog-archive/where-are-sensors-used->

¹¹ <https://www.educba.com/applications-of-sensors/>

¹² shorturl.at/nDRV7

Cause

There are several reasons why the level of carbon monoxide rises. Because combustion is required to produce carbon monoxide, the cause will be found in heating appliances, hot water systems and gas cookers.

Lack of air supply

Today people insulate their houses very well. As a result, little fresh air is sometimes allowed into the room. This shortage of fresh air (oxygen) causes CO formation in the heating appliance. If this compound is released into space, there is a real danger of CO poisoning.

Problems with appliances

Due to a problem with a (water) heating appliance, CO can be released into the home. In particular, appliances for the production of hot water remain the most important source of intoxication. Older devices are generally less safe than the new ones.

The most common problems with these devices are:

- lack of connection to a chimney which discharges the combustion gases
- poor regulation, installation or maintenance of appliances
- incorrect use
- use in a room that is too small and poorly ventilated

Problems with flues gas discharge or chimney¹³

Many houses still have a chimney built for coal appliances. However, often a high-efficiency gas or fuel-oil appliance is now connected to it, so that the chimney is not adapted to the needs of the new appliance. The maintenance of the chimney is important and should be done regularly.

Unfavorable weather conditions

Most accidents due to CO poisoning occur between November and April. In some weather conditions, combustion gases are not removed as well or less ventilation is possible. These conditions increase the risk of CO poisoning.

The highest risk is:

- in cold weather when you keep all doors closed and cover the cracks
- when it gets slightly warmer and the heaters are closed, so that there is little oxygen supply and combustion is very incomplete
- in calm and stable weather when the chimneys do not draw as well
- in very windy weather when the combustion gases are blown back into the drain

The weather conditions cause both a backwash and an inversion.

Backwash of combustion gases

Backwash means that the combustion gases end up in the house via the chimney instead of into the outside air. This risk of recoil is greatest in windless, foggy weather or on sunny days during a colder period (mainly in autumn, winter and spring).

¹³<https://www.cm.be/gezond-leven/omgeving/co-vergiftiging-voorkomen/risicofactoren>

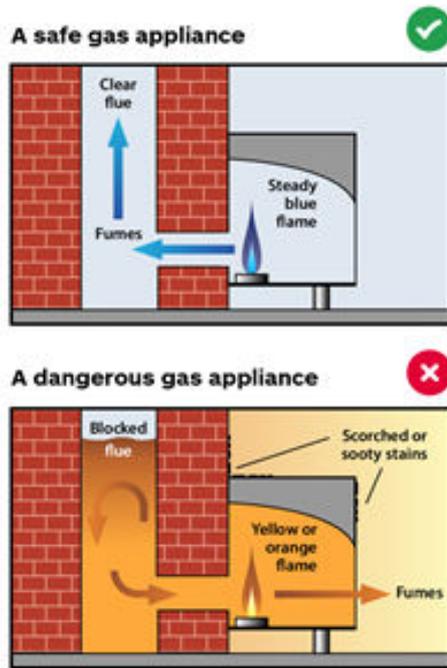


Figure 26: Scheme comparing a safe and dangerous appliance, respectively¹⁴

Temperature inversion

Normally, the temperature decreases with altitude. This does not happen with inversion, which creates a layer of warm air to a certain extent (especially in winter). This warm layer ensures that chimneys 'draw' less well and that the air in the environment is not refreshed much. As a result, combustion gases are poorly removed, and the risk of CO poisoning is much greater. During the weather report, a warning triangle indicates that the weather is an additional risk factor for CO poisoning. If there are already a few risk factors in the house, it can again be a deciding factor for CO intoxication.

Human behavior

A higher CO risk arises from improper or incorrect use of appliances such as:

- leave the auxiliary heater on for too long
- long-term use of a kitchen water heater without a chimney connection for a shower or bath
- setting a heating appliance that is too powerful in a room that is too small to a setting that is too low
- close all cracks with draft strips
- appliances and chimneys poorly or not maintained
- sealing ventilation grids because of the cold

¹⁴
safety/sources

<https://www.npower.com/help-and-support/emergency-information/carbon-monoxide-safety/sources>

How can you detect CO?¹⁵

It is difficult to determine carbon monoxide itself. It is a gas you cannot smell, taste or see. There are only a few ways in which you can detect it yourself.

Be especially alert in the following situations:

- one person in the family is uncomfortable in the bathroom, where a gas boiler or geyser is installed
- several family members in the same room all feel sick (nausea, headache, dizziness, vomiting and stomach pain, but without diarrhea)

The symptoms of carbon monoxide poisoning are similar to the symptoms of the flu. This is why most people think of the flu first and do not consider carbon monoxide poisoning.



Figure 27: Symptoms of carbon monoxide poison¹⁶

What do you do if you suspect CO is involved?

1. Immediately open all windows and doors in the house if you suspect carbon monoxide
2. Call the emergency services on 112 and explicitly state that you think it is CO poisoning
3. If you think you know which appliance is responsible for the carbon monoxide, switch it off
4. If there are any victims, get them out of the room and see if you should start CPR. Be careful not to get intoxicated during this entire process

¹⁵ <https://bit.ly/2TcJzpq>

¹⁶ <https://bit.ly/2RvDvlh>

Dangers of CO depending on its concentration

Concentration (ppm)	Effects of exposure to CO (Time Based Mean / TWA)
6	Maximum permissible concentration for continuous exposure hour period according to WHO
150	Slight headache after 1,5 hours
200	Slight headache, fatigue, nausea after 2-3 hours
400	Frontal headache within 1-2 hours life threatening after 3 hours
800	Dizziness, nausea and convulsions within 45 minutes Unconscious within 2 hours Death after 2-3 hours.
1600	Headache, dizziness and nausea within 5-10 minutes. Death 25-30 minutes
3200	Headache, dizziness and nausea within 5-10 minutes. Death 25-30 minutes
6400	Headache, dizziness and nausea within 1-2 minutes. Death within minutes
12800	Death within 1-3 minutes

Figure 28: Table of effects of CO according to its concentration¹⁷

Example of a carbon monoxide sensor¹⁸

The MQ7 sensor is a carbon monoxide sensor. It detects the concentration of CO, in particles per million (PPM) in the air. This type of sensor can measure concentrations ranging from 20 to 2000 ppm. Thanks to its high sensitivity, fast response time and low cost it is the perfect candidate for various CO detection equipment in homes, cars or industries. It can also be used to detect a certain amount of CO in different gases. The output of the sensor is an analog resistor.

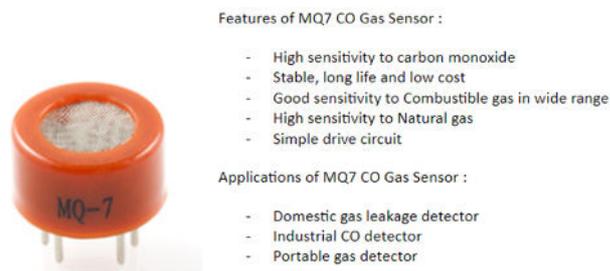


Figure 29: Representation of the sensor with its features and applications¹⁹

¹⁷ <https://www.feenstra.com/onderhoud/koolmonoxide/>

¹⁸ <https://www.sparkfun.com/products/9403>

¹⁹ <https://www.electroniccomp.com/mq7-gas-sensor>

6.5.2 Temperature

Why

Temperature and humidity

As already discussed, temperature and humidity²⁰ are closely related. Warmer air can absorb more moisture than cold air. As a result, the relative humidity of cold air is higher than that of warm air. Too low humidity is not healthy for the airways, but at the same time too high humidity can cause fungal infections, which can be extremely dangerous for one's life.

Temperature and comfort

Most people are comfortable with a temperature^{21,22} between 20 and 22 degrees Celsius. Above that range it is too warm, below it - too cold. The temperature range at which the person feels comfortable depends strongly on one's preferences and physical attributes, for example, fat percentage plays a huge role (skinny people get cold faster). Age is also important; older people are more likely to get cold. While feeling cold, the combustion in the body increases so more energy is used, and also blood vessels tend to constrict. Keeping the comfortable temperature level is good for your general health and well-being.

Temperature depending on the room^{23,24}

Living room

The living room is the place where you can relax, watch TV or do some strumming on your laptop. Most people find 20 degrees ideal for this space.

Kitchen

The kitchen does not need to be heated as much. Because steam escapes from your pots, heat comes from the oven and you are often busy washing dishes or cutting vegetables, a temperature of 18 degrees is optimal.

Bathroom

The bathroom may be a bit warmer again - about 23 degrees. But make sure that you only allow the temperature to rise when you actually use the space! Taking a shower or getting ready does not take very long, and when you are done with that, the bathroom can cool down a bit.

Bedroom

The temperature in the bedroom is different from the rest of the house. We prefer to use thick blankets when sleeping. You sleep best when it is slightly cooler in the room than average. The blankets

²⁰ <https://www.samenmetenaanluchtkwaliteit.nl/zelf-meten-0/welke-stoffen-kan-ik-meten>

²¹ <https://www.bouwenwonen.net/artikel/De-gezondheidseffecten-van-de-ideale-temperatuur-in-huis/43313>

²² <https://www.bcdadvies.nl/warmtecomfort-gemeten-versus-gevoelstemperatuur/>

²³ <https://www.ovoenergy.com/guides/energy-guides/average-room-temperature.html>

²⁴ <https://informazout.be/nl/blog/de-ideale-temperatuur-voor-elke-kamer-huis>

provide sufficient warmth, while you have nice fresh air around you. The bedroom temperature is best around 16-18 degrees. Also hang a thermometer in the bedroom.

Comfort temperature^{25, 26}

It is common knowledge that the ideal temperature is very personal, but that you feel that the ideal temperature depends on the activity you perform and the clothes you wear. There is a small layer of air around your skin that keeps you warm. When you are wet, that protection is lost. That is why wind or draft also feels fresh: the rapid air displacement blows away this layer of air and the heat.

And yet there is a lot to say about comfort temperature. Comfort temperature is the average of the air temperature and the radiant temperature of walls, windows, floors, in short: everything around you.

People sometimes think that only the indoor air should be heated. This is not entirely correct. Your body also feels the heat of the things around you: the radiant temperature. Warm walls and windows feel comfortable. That is why floor and wall heating is such a comfortable heating method.

Cold (uninsulated) walls, floors or windows have a low radiation temperature. To compensate for this, the air in the house will have to be warmer to keep it pleasantly warm. In old poorly insulated houses, the thermostat is often set at 22°C or higher. Not only do you have to heat the room extra to get the room warm, also you need to heat the room extra warm to have a pleasant feeling.

The reverse also applies: in a well-insulated house with warm walls and super-insulating glass, it is already pleasant if you set the thermostat to 19 or 20°C. It is therefore important to insulate the house properly. Living in a house like this will indeed feel better and it is also advantageous in terms of finances.

Temperature sensor

We do not need to buy an additional sensor to take a temperature reading. We use the DHT22 sensor as a humidity sensor. This can also measure the temperature to an accuracy of 0.5°C and has a measuring range of -20 to 125°C. This makes it definitely suitable for our project.



Figure 30: Temperature sensor DHT22²⁷

²⁵ <https://www.bcdadvies.nl/warmtecomfort-gemeten-versus-gevoelstemperatuur/>

²⁶ <https://www.bouwenwonen.net/artikel/Hoe-zie-ik-toe-op-een-gezonde-woonomgeving-Met-ventilator-en-hygrometer/41765>

²⁷ <https://core-electronics.com.au/dht22-temperature-and-relative-humidity-sensor-module.html>

6.5.3 Carbon dioxide

Why

Carbon dioxide, also known as CO₂, is a non-toxic and non-flammable gas²⁸. However, a larger amount of CO₂ in space displaces the oxygen uptake in our body and that phenomenon is not desirable. Because this displacement takes place, the body switches to a lower energy use throughout the day and this action then produces specific complaints such as fatigue, headache and loss of concentration.

CO₂ concentration is a good indicator of other pollutants spread by people and a good indicator of ventilation in rooms where people are present.

Symptoms

To reduce the amount of CO₂ in a room, a continuous guaranteed supply of fresh air, ventilation, is necessary. In the absence of ventilation, non-specific complaints arise such as “stale air”, “stuffy atmosphere”. In addition to these causes for discomfort, a too high concentration of CO₂ also has health-related risks:

- headache, tiredness and drowsiness (often increasing during the day)
- mucous membrane irritations and other non-specific complaints (headache, fatigue, irritations, etc.)
- transmission of infectious diseases leading to an increase in absenteeism (colds, flu and the like)
- worsening of allergies (hay fever, food allergies, etc.)
- increased risk of asthma attacks

The CO₂ content is expressed in ppm units (parts per million).

Guidelines for CO₂ in indoor areas

There are guidelines²⁹ that indicate how much CO₂ may be present in the house. Three different colors are used to create a good overview between the different values.

- green: 400 to 800 ppm is good (± 400 is the outside air level)
- orange: 800 to 1200 is medium
- red: 1200+ is bad (1200 is really the indoor air limit, ventilation is necessary)

If there is too much CO₂ in the air, you need to ventilate your home. Doing this will lower the CO₂ values.

6.5.4 Pressure sensor

General information

A pressure sensor³⁰ can sense a pressure signal and convert it into a usable output electrical signal in accordance with certain rules.

²⁸ <https://www.co2indicator.nl/>

²⁹ <https://www.ventilatieland.nl/blog/169/co2-oorzaak-gezondheidsklachten.html>

³⁰ <https://www.utmel.com/blog/categories/sensors/working-principles-and-applications-of-pressure-sensors>

Pressure is the force applied by the liquid, gas or solid on a surface usually measured in units of force per unit of surface area. Common units are Pascal (Pa), Bar (bar), N/mm² or psi (pounds per square inch).

Division of pressure sensors **accordingly with the working principle:**

- **piezoelectric pressure sensor**³¹

The principle of operation is based on the piezoelectric effect which is an ability to generate an electric current in response to mechanical stress. When piezoelectric material is subjected to external stress, a shift of the positive and negative charges in the material occurs, whose result is then an external electrical field. The reverse phenomenon happens when an outer electrical field either stretches or compresses the piezoelectric material.

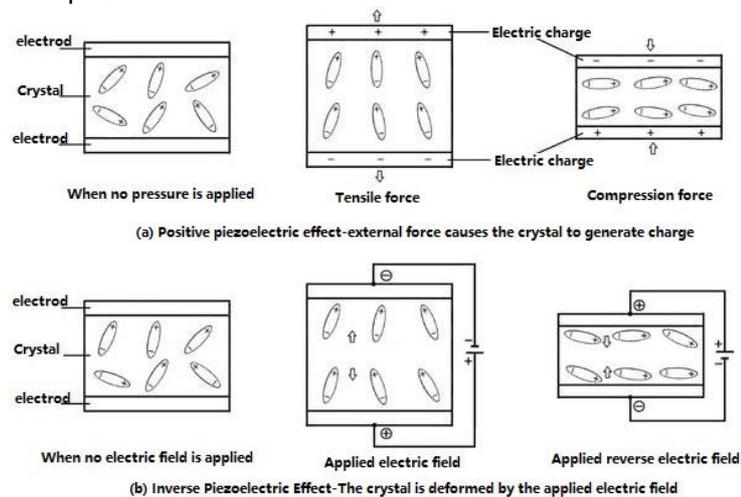


Figure 31: Depiction of piezoelectric effect³²

- **strain gauge pressure sensor**³³

The resistance strain gauge is a sensitive device that converts the strain change on the test piece into an electrical signal. It is one of the main components of the piezoresistive strain sensor. The strain gauges attached to the container and subjected to the applied pressure, change the dimensions depending on the expansion or contraction of the container. The change of dimension of the strain gauge also makes the resistance to change. This change becomes an indicator of pressure applied to the container (elastic container or cell).

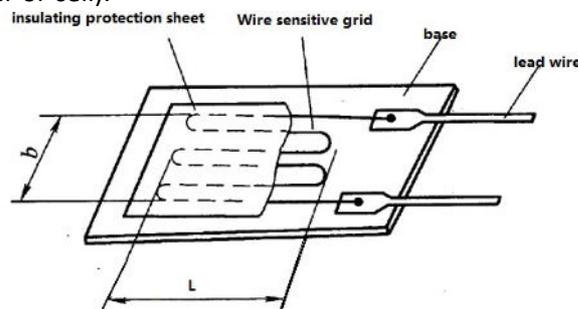


Figure 32: Metal resistance strain gauge³⁴

- **capacitive pressure sensor**

³¹ <https://www.nanomotion.com/nanomotion-technology/piezoelectric-effect/>

³² <https://www.utmel.com/blog/categories/sensors/working-principles-and-applications-of-pressure-sensors>

³³ <https://instrumentationtools.com/strain-gauge-pressure-sensor-principle/>

³⁴ <https://www.utmel.com/blog/categories/sensors/working-principles-and-applications-of-pressure-sensors>

A capacitor is used to store electrical charge and electrical energy. It includes at least two electrical conductors separated by the given distance. The space between the capacitor plates may be simply a vacuum (vacuum capacitor) or the space can be filled with so-called dielectric material. The amount of energy that can be stored by the given capacitor is called capacitance.³⁵

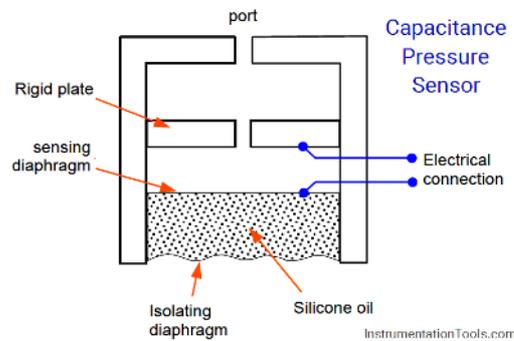


Figure 33: Scheme of the capacitive³⁶

Capacitive pressure sensors operate on the detection of the changes in electrical capacitance caused by the moving of diaphragms. If the sensing diaphragm, present between two capacitor plates, deforms because of a differential pressure, an imbalance of capacitance will occur between the diaphragm and the two plates.³⁷

- **resonant pressure sensor**

Resonant frequency is the oscillation of a system at its natural or unforced resonance.³⁸ Resonant pressure sensors usually use a resonating mechanical structure, for instance, a vibrating beam as a strain gauge in order to sense a deflection of the pressure sensitive diaphragm. The basic principle of operation is simple - the pressure deflects a diaphragm, which in turn applies axial stresses to a beam that is vibrating at its resonant frequency. The change in resonant frequency is then noticed and used as an output to indicate the applied pressure based on the calibration.³⁹

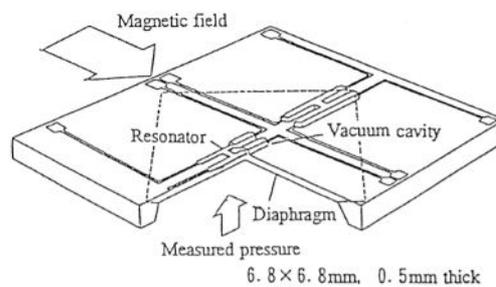


Figure 34: Structure of resonant pressure sensor chip⁴⁰

Division of pressure sensors accordingly with the **types of pressure measurements:**

³⁵ <https://openpress.usask.ca/physics155/chapter/4-1-capacitors-and-capacitance/>

³⁶ <https://instrumentationtools.com/capacitive-pressure-sensor/>

³⁷ <https://bit.ly/3bJolk4>

³⁸ <https://bit.ly/2SbV6EV>

³⁹ Huang, Qing-An (2018). [Micro/Nano Technologies] Microelectromechanical Systems. A Micromachined Silicon Resonant Pressure Sensor., 10.1007/978-981-10-5945-2 (Chapter 15), 387–419. doi:10.1007/978-981-10-5945-2_15

⁴⁰ Kinji Harada; Kyoichi Ikeda; Hideki Kuwayama; Hidekazu Murayama (1999). Various applications of resonant pressure sensor chip based on 3-D micromachining.,73(3),261–266. doi:10.1016/s0924-4247(98)00245-3

- **absolute**⁴¹

The absolute measurement is made possible by measuring the target pressure relative to the known pressure of an absolute vacuum. The principle of operation of a pressure sensor using absolute measurement is based on the presence of the sealed vessel as the reference point and a sensing technology is then applied to the surface of the vessel whose electrical characteristic varies with changes in strain. There are many different approaches to this.

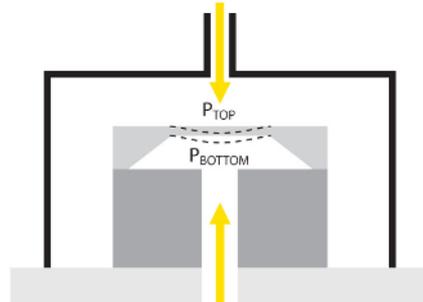


Figure 35: Absolute pressure sensor⁴⁰

- **gauge**⁴²

This type of sensor is usually used when the exact value of the pressure or vacuum or the exact pressure generated are not of the utmost importance. Instead, it is used when one wants to obtain information about how much the pressure or vacuum differs from the atmospheric pressure. Atmospheric pressure varies across the globe depending on our altitude and even changes in the weather. A gauge pressure sensor measures the pressure at its port with respect to the atmospheric pressure.

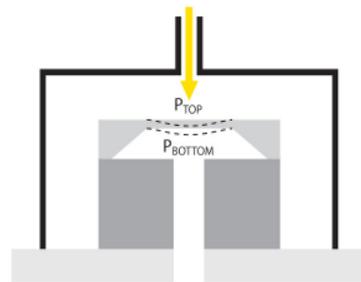


Figure 36: Gauge pressure sensor⁴⁰

- **differential**⁴³

Another group of pressure sensors is differential pressure sensors. Sometimes it is enough to know a difference between two points in the system being monitored. The differential pressure sensors give comparative measurements between two points. Typically, the two pressures to be measured are applied to opposite sides of a single diaphragm. The deflection of the diaphragm, either positive or negative with respect to the resting state, determines the difference in pressure. The measurements conducted by the differential pressure sensors are fully dependent on the atmospheric pressure.

⁴¹<https://bit.ly/3f75Q0m>

⁴²<https://www.avnet.com/wps/portal/abacus/solutions/technologies/sensors/pressure-sensors/measurement-types/gauge/>

⁴³<https://www.avnet.com/wps/portal/abacus/solutions/technologies/sensors/pressure-sensors/measurement-types/differential/>

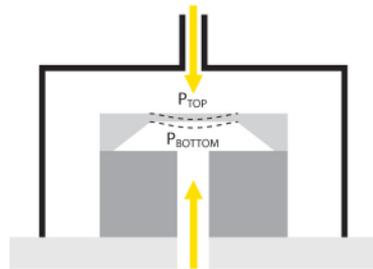


Figure 37: Differential pressure sensor⁴⁰

Applications

- water conservancy and hydropower;
- railway transportation;
- intelligent buildings;
- production automatic control
- aerospace;
- military industry;
- petrochemical.

6.5.5 Motion sensors

Division of motion sensors:

- **Active Detectors**⁴⁴- these are also known as the radar-based motion sensors. They emit electromagnetic waves, either in the form of radio waves or microwaves. Nearby objects are struck by the emitted waves, and these are reflected to the sensor/detector. The sensors look for a frequency shift in the wave, when an object moves in a sensor-controlled space at that time. These changes are understood by the motion sensor and an electrical signal is sent further to the proper devices, for instance, the alarm system.

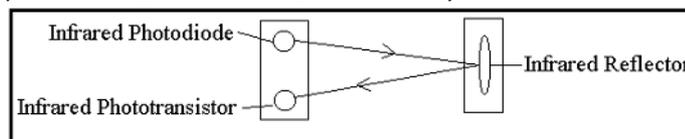


Figure 38: Scheme of an Active Infrared Motion Detector⁴⁵

- **Passive Infrared (PIR)** - by looking for changes in temperatures, passive infrared sensors detect body heat (infrared energy). They are the most frequently used motion sensor in home security systems.

Upon warming up, the PIR motion sensor is able to detect heat and movement in the surrounding areas, creating a protective “grid.” When a moving object blocks too many grid zones and therefore the infrared energy levels change rapidly, the sensors trigger an alarm.⁴⁶ Passive infrared motion sensors are small, low power, easy to use, and inexpensive.⁴⁷

- **Dual Technology** - a dual technology motion sensor is more false-alarm resistant because it requires two sensors to be triggered in a certain way.

⁴⁴<http://www.radanpro.com/Radan2400/ALARMI/Active%20IR%20Motion%20Detector%20Project.htm>

⁴⁵ <http://www.radanpro.com/Radan2400/ALARMI/Active%20IR%20Motion%20Detector%20Project.htm>

⁴⁶ <https://www.safewise.com/resources/motion-sensor-guide/>

⁴⁷ <https://www.arrow.com/en/research-and-events/articles/how-motion-sensors-work>

Dual technology motion sensor is a technology that incorporates both PIR and microwave sensors to avoid false alarms. A sudden increase of temperature can cause the PIR to go off and at the same time a wind can move an object and trigger the microwave sensor. Thanks to the hybrid technology, both sensors will need to detect changes that trigger them, causing the probability of the false alarms to be extremely low.

Motion sensors' principle of operation

Motion detecting using timer

Different controllers like 555 timers are often used to implement motion detector circuits, timers, microcontrollers, etc., and also different sensors like IR, PIR, and the Ultrasonic sensors.

Two sections are present in motion: transmitter and receiver. In those 555 timers, IR sensors, photo transistor, another 555 timer, and an alarm are used in the respective sections.

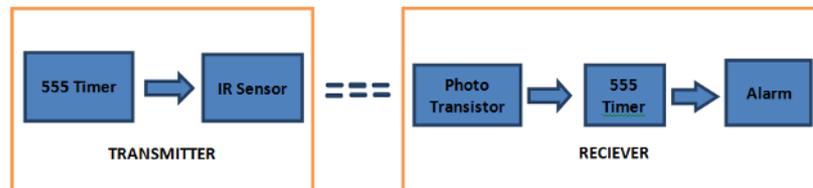


Figure 39: Block diagram of motion detector⁴⁸

The output of the sensor relies strictly on the fact whether there occurs or not an interruption between the IR sensor and phototransistor. If such interruption is not present, the frequency will be in one phase, and because of this fact the circuit will not indicate any output on the receiver side. However, if an interruption does occur, the detected frequency will be in a different phase. This triggers the timer to give a buzzing sound.

Motion detecting using microcontroller^{49,50}

In motion sensors it is also possible to use a microcontroller as a main controller similar to the timer. This system also uses an ultrasonic sensor to detect the motion of any object. As the name implies the ultrasonic sensor detects an object utilizing the soundwaves of the particular frequency.

Application of an electrical pulse of high voltage to the ultrasonic transducer causes the vibration across a specific spectrum of frequencies and generation of a burst of sound waves. In case any obstacle comes close to the ultrasonic sensor, the sound waves reflect back in the form of echo and generate an electric pulse. The time taken between sending sound waves and receiving the echo is calculated. Next, there is a comparison between the echo patterns and the patterns of sound waves in order to determine the condition of a detected signal.

⁴⁸ <https://www.electronicshub.org/motion-detector-circuit/>

⁴⁹ <https://www.elprocus.com/ultrasonic-detection-basics-application/>

⁵⁰ <https://www.elprocus.com/motion-detector-circuit-with-working-description-and-its-applications/>

6.5.6 Humidity sensor

Why?

The humidity⁵¹ is a very important factor in the house. Not only is it important for your health but also for your animals, plants, furniture and the electronic devices in your home. Both too low and too high humidity in the house can cause a variety of complaints.

When the humidity is too high it can have some negative health consequences. Some examples of the negative consequences are:

- Allergic reactions
- Stuffiness
- Headache
- Cough
- Common cold
- Skin irritation

Too high humidity

Not only are there negative consequences for the health. It is also very bad for the house since a humid environment is an ideal breeding ground for fungi. The fungi can grow on your walls, furniture and other wooden parts of the house. These are not the only things that can happen in a house with a too high level of humidity. Other factors that can occur are musty smell, change of colors within the walls, swelling of wooden floors and many more. If the humidity is at its highest wallpaper can come off the wall and paint can peel off walls and ceilings.

Too low humidity

It is also possible that the humidity is too low at your home. It can also have some negative consequences. Dry air in the house has the additional effect of releasing dust earlier and making it float. There are also some negative consequences for your health, some examples for this are:

- Drying out of the mucous membranes
- Dry cough and tickling cough
- Flaking of the skin
- Dry and sometimes cracking lips
- Dry eyes
- Loss of concentration
- Fatigue
- Headaches
- Irritation of the airways
- Decrease in oxygen uptake

Causes of low/high humidity in the house

As mentioned, too high or too low humidity is detrimental. If you want to make sure that you have a good humidity level in your house, you first have to start by finding the reasons why you have too high or too low humidity. The ideal humidity level in a house is between 40% and 60%.

The most popular causes that can cause an abnormal humidity in the house are:

⁵¹<https://bit.ly/3ww6c6n>

- Dysfunctional ventilation
- Leakage (rain, shower etc.)
- Accumulation of moisture in cold places (condensation)
- Insufficient / improper ventilation

Solutions⁵²

Increased humidity

It's possible to increase the humidity of the air in the house in various ways. The easiest way to increase humidity is to hang a bowl of water on the heater. The heat from the heater will cause the water to evaporate and mix with the air in the home. Of course, this also has its disadvantages as to make sure you change the water regularly. It's important to do this because stagnant water is a breeding ground for bacteria. The biggest disadvantage of this way of controlling humidity is that you cannot regulate it. So it is a good way when you always have too low humidity.



Figure 40: Picture of a heater with a bowl of water hanging on

Another way to increase humidity is to use a humidifier. This device will also increase humidity by evaporating water. The advantage of this device is the control of the humidity. As expected, this way of increasing humidity is more expensive. Both the purchase price and the electricity that the device requires are higher than the price of the little bowl of water that you hang against your heater. The tray of water does not even have running costs, this is because it uses the heat from the heater and does not need extra energy.



Figure 41: Humidifier⁵³

⁵² <http://www.luchtvochtigheid.net/luchtvochtigheid-tips/>

⁵³ <https://bit.ly/3fGTMSm>

Decreased humidity

Just as there exist different ways of increasing humidity, it's possible to find different ways of decreasing it.

The easiest way to reduce humidity is to use an air freshener. These usually look like a small plastic cage that is half open at the top so that air can easily enter the container, but water cannot escape from it. The moisture absorber attracts the moisture from the air. It is a magnet for the moisture in the air. The moisture is then collected in the plastic tray. This is the cheapest way, but the humidity can't be controlled with it. It continues to extract moisture from the air even when there is less than 60% humidity.



Figure 42: Air freshener⁵⁴

Another way to lower the humidity is to use a dehumidifier. This device sucks up the moist air, after which the air is filtered. By filtering the air, the dirt and dust particles will also be stopped by the filter in the dehumidifier. In addition, the air is cooled so that the moisture in the air is condensed. In the next section it will be discussed how this happens using the Mollier diagram. Also here is the purchase price and the using price higher. The reason why the using price is higher is because the dehumidifier needs electricity to work.

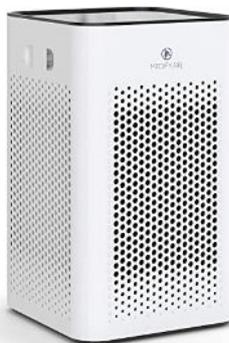


Figure 43: Dehumidifier⁵⁵

Types of humidity sensor

There are two types of humidity sensors that can be used for the project. DHT11 and DHT22 are both^{56,57} humidity and temperature sensors.

⁵⁴ <https://bit.ly/3hREDkd>

⁵⁵ https://m.media-amazon.com/images/I/81kJcvx+uVL._AC_SS450_.jpg

⁵⁶ <https://learn.adafruit.com/dht>

⁵⁷ <https://howtomechatronics.com/tutorials/arduino/dht11-dht22-sensors-temperature-and-humidity-tutorial-using-arduino/>

Looking at the range of the sensors, it's possible to see that the range of DHT22 is bigger than the range of DHT11. The range of DHT11 is big enough for the project. Furthermore, the DHT22 is more accurate than the DHT11, that is the reason why the DHT22 would be more adapted to the project. The main advantage of these sensors is the fact that humidity and temperature could be measured with the same sensor at the same time.



DHT11	Temperature Range	DHT22
0 - 50°C / ± 2°C		-40 - 125 °C / ± 0.5 °C
20 - 80% / ± 5%	Humidity Range	0 - 100 % / ± 2-5%
1Hz (one reading every second)	Sampling Rate	0.5 Hz (one reading every two seconds)
15.5mm x 12mm x 5.5mm	Body Size	15.1mm x 25mm x 7.7mm
3 - 5V	Operating Voltage	3 - 5V
2.5mA	Max Current During Measuring	2.5mA

Figure 44: Comparison DHT11 and DHT22⁵⁷

Air quality

Definitions

Absolute humidity⁵⁸ is the amount of humidity that can be expressed in an absolute quantity. This is the amount of water in a fixed quantity of air. It is expressed in grams of water per kilogram of air.

Relative humidity is the ratio of the amount of water vapor in the air to the maximum amount of water vapor the air can absorb. The relative humidity depends on the temperature (and air pressure, which you cannot control and does not play an important role in "normal" life).

A relative humidity of 100% does not mean that your house is under water, but it does mean that the air cannot contain more water vapor. So, if you produce more water vapor, it will condense.

Mollier diagram

"Air is a mixture of mostly oxygen, nitrogen and water vapor. The Mollier diagram is a graphic representation of the relationship between air temperature, moisture content and enthalpy."⁵⁹

The Mollier diagram tells exactly what the condition of the air is. It's possible to read off how many grams of water there are in a kilogram of air.

⁵⁸https://www.joostdevree.nl/shtmls/relatieve_vochtigheid.shtml#:~:text=Bij%20een%20binnentemp,eratuur%20van%200,%2C0%20gram%2Fm3%20aanwezig

⁵⁹ https://www.engineeringtoolbox.com/psychrometric-chart-mollier-d_27.html

The relative humidity of the air depends on the temperature and absolute humidity of the air. Based on these two quantities you can determine the relative humidity of the air using the Mollier diagram.

The absolute humidity is marked blue in the diagram. Temperature is marked green on the diagram. Relative humidity is marked in red.

As visible on the graph, there is more water vapor in the air when the temperature is higher at the same relative humidity. This is why it is important that you do not ventilate your house in winter by opening windows when your relative humidity is lower than 40%. The cold air coming in holds little water vapor, when it comes in the air will warm up causing the relative humidity to drop.

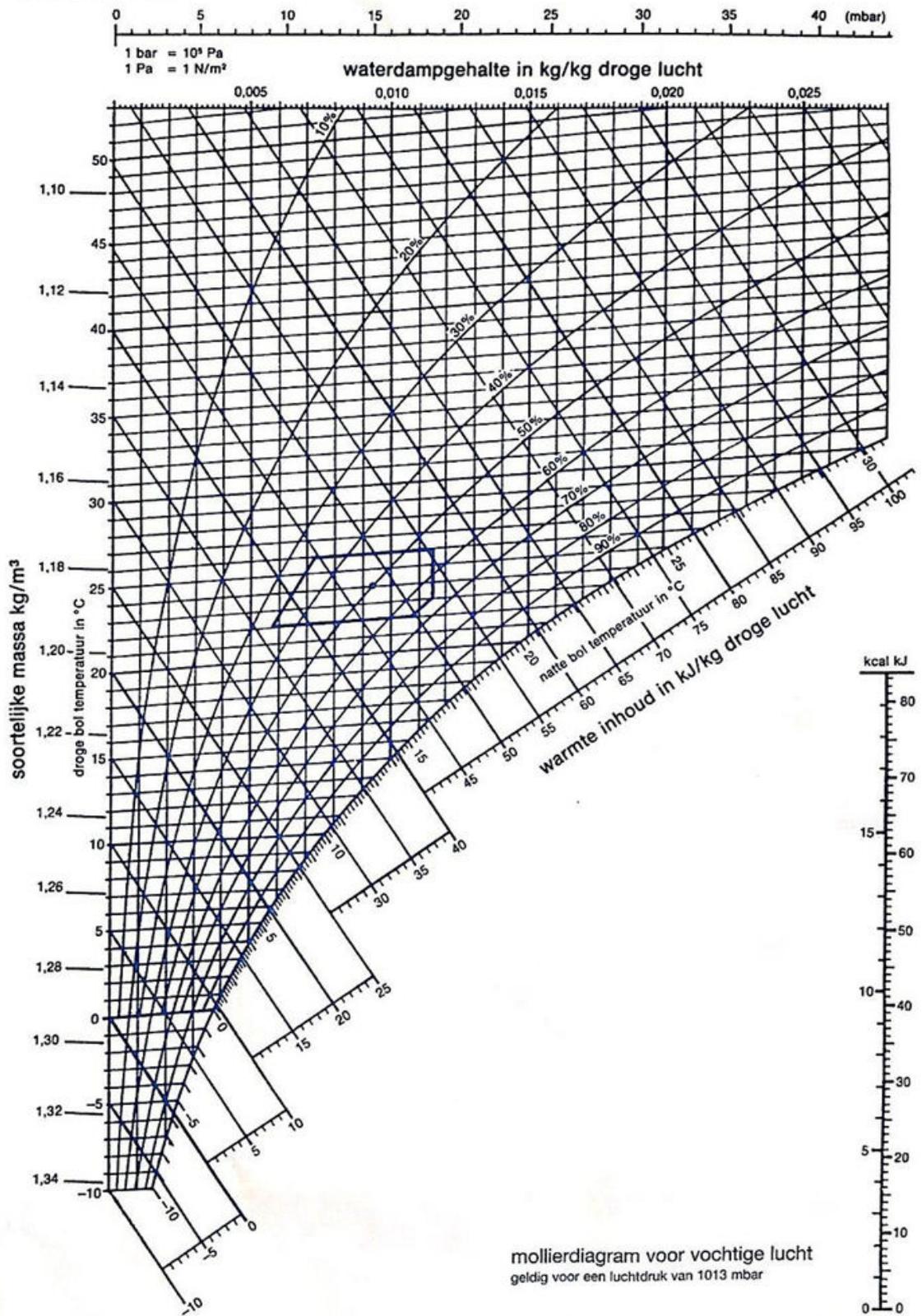


Figure 45: Mollier diagram⁶⁰

⁶⁰ https://www.engineeringtoolbox.com/psychrometric-chart-mollier-d_27.html

6.5.7 GPS Sensor

Definition of GPS

Global Positioning System is a satellite-based navigation system, which is made up of at least 25 satellites and shortened to GPS. It is not bound to any weather conditions, can work without a subscription, is available on the whole world and that for 24 hours a day.

How does GPS work?

The combination of the GPS satellites circle the Earth in a precise orbit. While they circle the Earth, they transmit a unique signal with orbital parameters. These allow GPS devices to compute the exact location of the connected satellite. Afterwards the GPS receivers use the given information and trilateration to calculate the device's exact location. The GPS receiver measures the distance to each satellite by the amount of time it takes to receive a signal. This calculation will be made to all connected satellites and with all this information the receiver can determine a device's position. To calculate a 2D position with latitude, longitude, and track movement the GPS receiver must be connected to at least 3 satellites. When the receiver is connected to 4 or more satellites, a 3D position can be determined. This includes the 2D position with extra altitude. In general, a GPS receiver is connected to 8 or more satellites, but this depends on the time of the day and position on the Earth. When the position is determined, the GPS unit can calculate more data, such as: Bearing, Track, Trip Distance, Speed and Distance to specific locations.

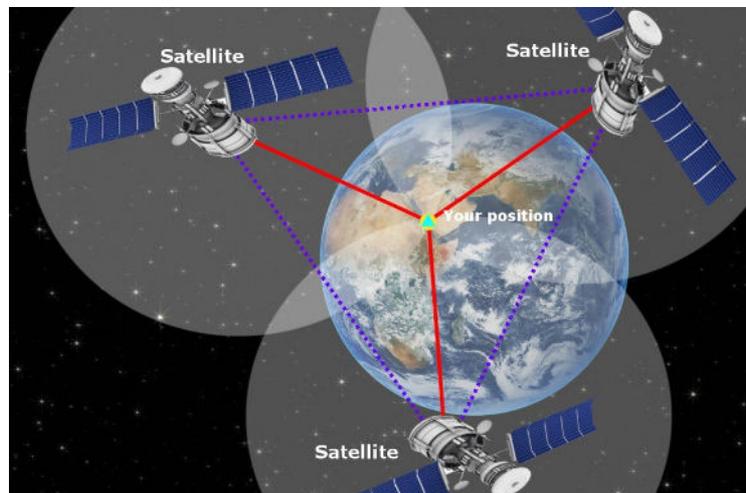


Figure 46: Triangulation with satellites⁶¹

What is the signal?

The GPS satellite transmits minimum 2 low-power radio signals. These signals travel by line of sight which means that they will pass through any object such as clouds, glass, plastic and many more. However, they cannot go through solid objects such as buildings and mountains.

⁶¹<https://www.scienceabc.com/innovation/how-gps-global-positioning-system-works-satellite-smartphone.html>

Modern receivers are built to connect with the satellites through houses as in any mobile phone.

The transmitted information contains 3 data's:

- ID of the satellite: identifies which satellite is transmitting information with the device
- Ephemeris data: determine the satellite's position, current date and time
- Almanac data: information about the whereabouts of the satellite at any time

6.5.8 Infrared fire sensor

General information

A fire/flame sensor is the type of sensor with the ability to detect a source of fire/flames and/or any other brighter light source through the detection of infrared light (electromagnetic wavelength of 760-1100 nm) emitted by the fire/flame. There are two types of flame sensor modules available on the market: three- and four-pin. The difference between those two modules is that the former provides only digital output, whereas the latter can provide both digital and analog outputs.

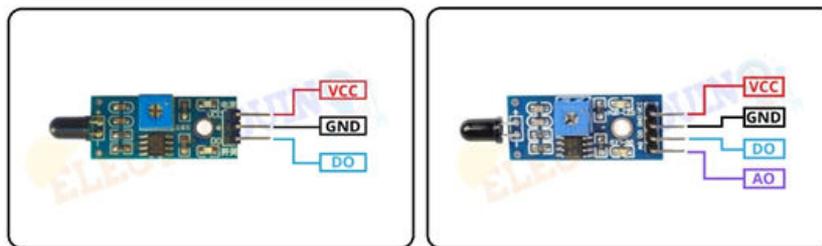


Figure 47: Comparison between the three-pin (left) and four-pin (right) sensor modules⁶²

As it may be observed in the scheme above, the phototransistor (the cylindrical part of the sensor) is coated by black epoxy which makes it sensitive to infrared radiation. It is used to sense flame or light in a range of 760 nm – 1100 nm wavelength. The sensor possesses two terminals: the longer and the shorter one. The longer one is the emitter and the shorter one is the so-called collector.



Figure 48: Phototransistor⁶³

Principal of operation

The whole operation principle is strictly based on the decrease of the resistance of the phototransistor present in the sensor when the IR light is detected. Therefore, logically, if the sensor

⁶² <https://www.electroduino.com/ir-infrared-flame-sensor-module/>

⁶³ <https://www.botnroll.com/en/infrared/3644-5mm-flame-sensor.html>

does not sense the presence of a fire/brighter light source, the resistance of the phototransistor is at its highest. Then the maximum voltage will be distributed across the phototransistor.⁶⁴

Applications⁶⁵

- hydrogen stations
- industrial and domestic heating system
- industrial fire detection
- fire alarms
- fire fighting robots and machines
- gas-powered cooking devices

6.5.9 Light sensor

General information

As the name implies, the light sensor measures⁶⁶ the number of photons and converts the information into electrical energy in the form of electrons. Light measured is an extensive property which means that the total of photons collected depends on the size of the collector. When talking about the light sensors, one has to mention the basic terms connected with the physics of light:

- candela - a unit describing luminous intensity. Logically, the higher the intensity of brightness of the light, the more intensive it seems to a human eye.
- lumen - a unit used to describe the luminous flux of the light bulb. It is a product of light intensity and the angle which the light beam occupies (expressed in steradians).
- lux - a unit used to properly measure the luminous flux harvested by a given surface, therefore the lux is expressed as 1 lumen per m²

The above-mentioned units are important in order to properly quantify the light into photons and later convert the information into useful signal.

Principal of operation

In general, there exist two types of light sensors that utilize two very different electrical components.

The first type of light sensor uses photodiode to measure the illuminance.⁶⁷ Photodiodes are usually made of silicon and germanium compounds and utilize optical filters, built-in lenses and surface areas. Photodiodes are based on the inner photoelectric effect in which, shortly speaking, an electrical current flow is caused by the appearance of electron-holes and those occur when a beam of light hits and electrons are loosened. The brighter is the light, the stronger is the electrical flow.⁶⁸

⁶⁴ <https://www.electroduino.com/ir-infrared-flame-sensor-module/>

⁶⁵ <https://www.elprocus.com/flame-sensor-working-and-its-applications/>

⁶⁶ <https://blog.endaq.com/how-light-sensors-work>

⁶⁷ <https://blog.endaq.com/how-light-sensors-work>

⁶⁸ <https://www.seeedstudio.com/blog/2020/01/08/what-is-a-light-sensor-types-uses-arduino-guide/>

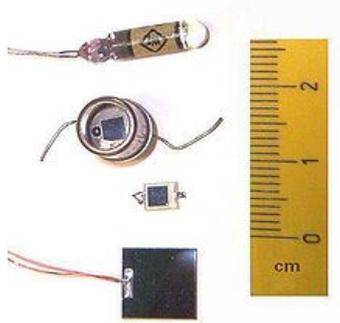


Figure 49: Examples of photodiodes⁶⁸

The second type of light sensor uses a phototransistor - a type of light-dependent transistor - which changes the resistance accordingly with the amount of light shining on it. This dependency is directly proportional, meaning that the more light is shining, the lower is the resistance. Usually, the photoresistor is made of highly resistant material cadmium sulfide, highly sensitive to visible and near-infrared light.

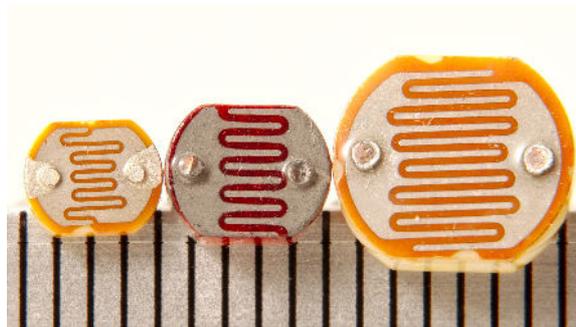


Figure 50: Examples of photoresistors⁶⁹

Applications⁷⁰

- consumer electronics, like, tablets, smartphones, etc.
- support of a driver's field of vision
- sprinkler systems used in agriculture
- alarms and security

A sensor is therefore a device that transforms data (which can be of different types such as biological, physical or chemical) into analytical data. The applications are very varied making them adaptable and useful in many fields. They can be used to study many elements or even almost everything that surrounds us.

⁶⁹ <https://steemit.com/science/@eneismijmich/introduction-to-electronics>

⁷⁰ <https://www.seeedstudio.com/blog/2020/01/08/what-is-a-light-sensor-types-uses-arduino-guide/>

6.6 Internet of Things (IOT)

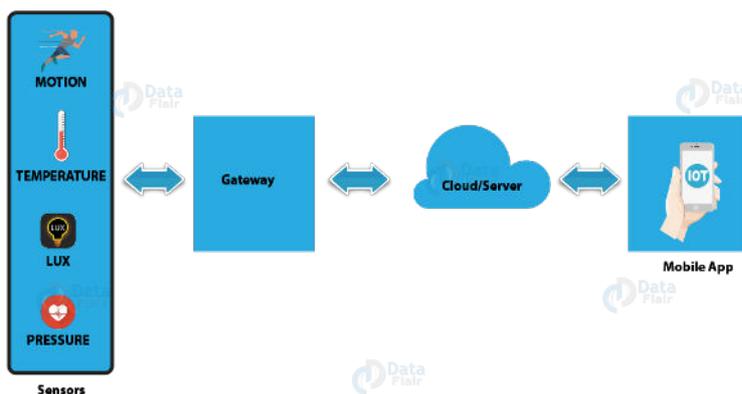
6.6.1 Introduction to IoT

Before elaborating wider on what the applications of IoT in the healthcare sector are, the whole idea of Internet of Things ought to be presented. Internet of Things⁷¹ simply speaking, it exceeds the Internet from connected computers to connected objects. Those said objects can be anything provided that they are connected to the Internet in-or directly. The main scope of this connection of different devices is to provide ubiquitous and pervasive access to various information, i.e. any information can be reached on any object in any place. Also, the system is able to transfer data through a network without requiring human-to-human or human-to-computer interaction.

The basic components of IoT are:

- sensors and/or actuators (e.g., display, sound, motors)
- computing resources - for processing data
- communication media: Bluetooth, ZigBee, RFID for a short range and the Internet for long range
- application interface - for accessing IoT services

It is with the help of IoT gateway (or through another peripheral device) that IoT devices can transmit and share the collected data.



and share the collected data.

This data is then sent to a cloud where it will be analysed.

The various devices can operate without human intervention (for the most part) but the latter can still interact with the devices to access the data, configure them or give new instructions. Different devices can communicate with each other and can act on each other according to the information received.

Figure 51: Simple scheme how IOT works

IoT is extremely important nowadays, it helps people in everyday life and work. Besides offering smart devices to automate homes, IoT is essential to business. It provides a real-time insight into how different systems really work, performance of machines and supply chains and logistics operations.

Some of IoT advantages include:

- information accessible from anywhere, at anytime and very easily
- improvement of connection and communication between different devices
- transfer of data over a connected network which results in saving of time and money
- improvement of the quality of lives, businesses, industrial sectors, healthcare via automatization of tasks
- reduction of need for human interaction

⁷¹ <https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT>

Some of the disadvantages of IoT include:

- increase of the number of connected devices (and therefore the increase of the information shared) is prone to being subjected to the hacker's attack
- managing multiple IoT devices, collecting and analysing data may be challenging
- occurrence of any bug in the system results in failing of the whole IoT connection
- because there is no international standard of compatibility for IoT, a huge difficulty for differently manufactured devices to communicate emerges

6.6.2 IoT in Healthcare Sector

Before IoT⁷² it was indeed impossible for doctors to monitor patients' health continuously and to make proper recommendations. The only possibilities for patients and doctors to communicate were visits and giving advice remotely. Internet of Things-based solutions have made health monitoring remotely⁷³ possible, making the patients feel safe and healthy, and empowering physicians to deliver superlative care. It has also engaged patients more and the satisfaction increased due to more efficient contact with doctors. IoT has an undoubted benefit, not only for doctors, nurses, and healthcare workers, but also for patients, their families, hospitals, and insurance companies.

IoT for Patients/Healthcare Workers

Patients' health and different parameters may be monitored via wearables like fitness bands, smartwatches or specially designated devices like cuffs monitoring heart rate, glucometers etc. These devices can be easily personalized and tuned to particular needs of the user. What is more, such devices may remind you of calorie count, exercise check, appointments, and much more.

IoT is indeed useful not only for the patients, but very often for their families. Any disturbance or change in the daily schedule of a person, alerting mechanism sends signals to family members and concerned healthcare workers. An example of the IoT devices used for remote monitoring of patients' health are sensors. A different electronic sensor connected to the patient could monitor vital statistics like chemical imbalances in the body, glucose level, nerve and brain activity, blood pressure, cardiac status, and further psychological and behavioural conditions. Also, various sensors implemented at home of an elderly person can provide support when an incident happens by rapidly informing family or caretakers.

The fast results can help doctors to correctly diagnose the patient, possibly saving a life. Further, using non-invasive IoT devices to monitor patients in hospitals, clinics, or at home can gather needed information about a patient over a long time, which can then be stored and analysed.

IoT for Hospitals

IoT may be used in hospitals for more technical aspects. IoT sensor-based devices are used for tracking real time location of equipment like wheelchairs, defibrillators, nebulizers, oxygen pumps and other monitoring equipment. What also can be tracked is the real-time location of medical staff

⁷² Pramanik, Pijush Kanti Dutta (2019). Healthcare Data Analytics and Management || Internet of things, smart sensors, and pervasive systems: Enabling connected and pervasive healthcare. doi:10.1016/B978-0-12-815368-0.00001-4

⁷³ <https://www.wipro.com/business-process/what-can-iot-do-for-healthcare/>

members. IoT devices also help in pharmacy inventory control, or environmental monitoring, for instance, checking refrigerator temperature, humidity and temperature control. In times of pandemic, it is really important to keep all the patients and employees safe and to prevent the spread of infections. IoT-based devices can help monitor the spread of infectious diseases.

IoT for Insurance Companies

It is possible for the insurance companies to use the gathered (through the IoT-based devices) data for their guaranteeing and claiming operations. IoT devices bring transparency between insurers and customers in the underwriting, pricing, claims handling, and risk assessment processes. IoT devices bring straightforwardness between insurers and customers in the underwriting, pricing, claims handling, and risk assessment processes.

6.7 Hardware

6.7.1 Raspberry Pi

Raspberry Pi^{74,75} is an inexpensive, small-sized computer that may be plugged into a computer or TV. In other terms, it could be described as a series of small single-board computers. The various Raspberry Pi products use an "open source" operating system. It ensures communication between the software, the hardware and the computer. This system is called Linux. The language that allows communication between all these elements is Python. It is used for websites, graphical user interface (GUI) applications or web applications. A huge advantage of this device is that the user does not need to possess knowledge about programming. Indeed, Raspberry Pi can interact with the world around us using data collection and interactions between different sensors. This system can be used in very simple projects such as counting items in an inventory to defining weather conditions accurately in a weather station.

There are different types of Raspberry Pi models. The most basic of them is called Raspberry Pi Zero (or Raspberry Pi Zero W when WIFI and Bluetooth functionality is added). This system is designed to be accessible to everyone and easy to learn. That's why you can find on the foundation's website many help and troubleshooting guides, blogs, commented project summaries, tutorials ... All this to allow an easy and self-taught or accompanied learning.

6.7.2 ESP32

What is the ESP32? It is above all a 32 bits microcontroller. It is composed of a full TCP/IP stack that allows a WIFI connection (thanks to the internet connection) and Bluetooth. All the state-of-the-art characteristics are featured like low-power chips, including fine-grained clock gating, multiple power modes, and dynamic power scaling. The combination of low costs and great power results in the opportunity to be connected to many other electronic devices, so therefore it is ideal for various IoT projects.⁷⁶

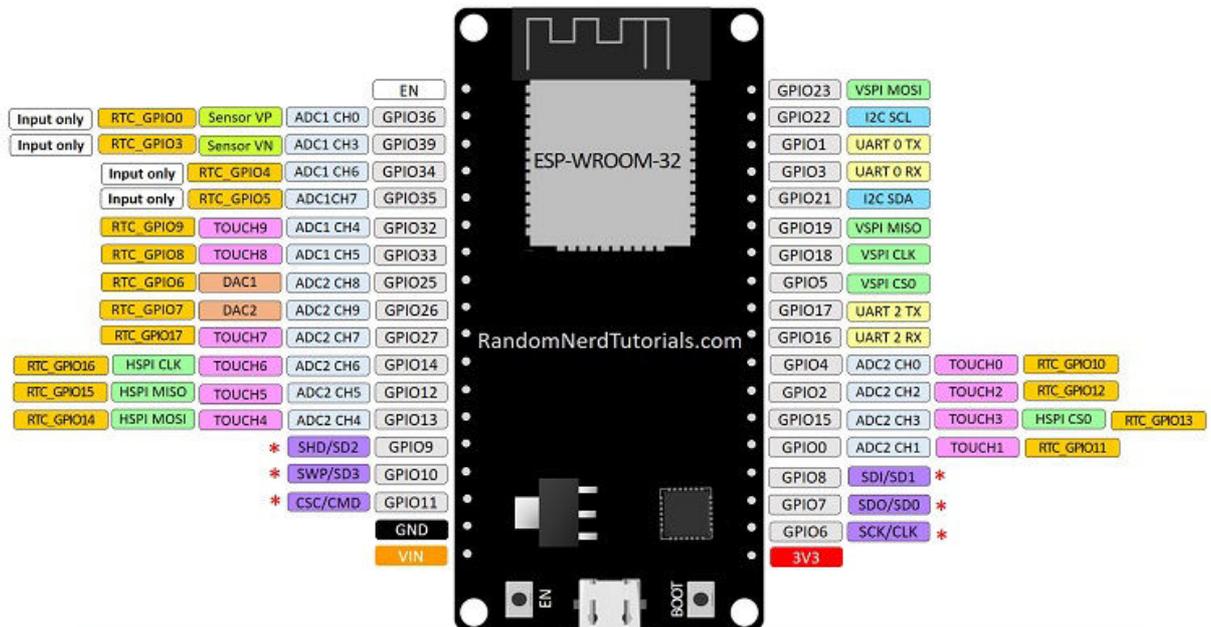
ESP32 possesses an antenna switch, RF balun, power amplifier, low noise receives amplifier, filters, and power management modules. As such, the entire solution occupies a minimal Printed Circuit Board (PCB) area. ESP32's integrated circuitry requires only 20 resistors, capacitors and inductors, one crystal and one SPI flash chip. ESP32 integrates the complete transmit/receive RF

⁷⁴ <https://www.piday.org/whats-a-raspberry-pi-and-how-does-it-wo>

⁷⁵ <https://www.raspberrypi.org/help/what-%20is-a-raspberry-pi/>

⁷⁶ <https://diyIoT.com/esp32-tutorial-what-do-you-have-to-know-about-the-esp32-microcontroller/>

functionality including antenna switches, RF balun, power amplifier, low noise receive amplifier, filters, power management module, and advanced calibration circuitries.⁷⁷



* Pins SCK/CLK, SDO/SD0, SDI/SD1, SHD/SD2, SWP/SD3 and CSC/CMD, namely, GPIO6 to GPIO11 are connected to the integrated SPI flash integrated on ESP-WROOM-32 and are not recommended for other uses.

Figure 52: General ESP32 scheme⁷⁸

Some of the applications⁷⁹ of the ESP32 are listed below, however, this is a non-exhaustive list:

- Generic Low-power IoT Sensor Hub
- Generic Low-power IoT Data Loggers
- Cameras for Video Streaming
- Over-the-top (OTT) Devices
- Speech Recognition
- Image Recognition
- Mesh Network
- Home Automation
 - Light control
 - Smart plugs
 - Smart door locks
- Smart Building
 - Smart lighting
 - Energy monitoring
- Industrial Automation
 - Industrial wireless control
 - Industrial robotics
- Smart Agriculture
 - Smart greenhouses
 - Smart irrigation
 - Agriculture robotics
- Audio Applications

⁷⁷ https://www.espressif.com/sites/default/files/documentation/esp32_hardware_design_guidelines_en.pdf

⁷⁸ <https://randomnerdtutorials.com/esp32-pinout-reference-gpios/>

⁷⁹ https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf

- Internet music players
- Live streaming devices
- Internet radio players
- Audio headsets
- Health Care Applications
 - Health monitoring
 - Baby monitors
- Wi-Fi-enabled Toys
 - Remote control toys
 - Proximity sensing toys
 - Educational toys
- Wearable Electronics
 - Smart watches
 - Smart bracelets
- Retail & Catering Applications
 - POS machines
 - Service robots

6.7.3 Smart devices

6.7.3.1 Philips Hue

Philips hue is a smart lighting system from Philips. There are many ways to wirelessly control your smart lights. By using a switch, you can turn your lamps on and off but also dim them. Switching is also very easy with your smartphone which makes wall switches superfluous. This lighting system consists of 4 different parts. You have the hue bulbs, the Hue bridge, the Hue app and Hue accessories.^{80,81}

6.7.3.2 Philips Hue Lights

The Hue lamps are smart and energy-efficient LED lamps. They are available in different types. You have three different types of lamps. You have the white series, these are the cheapest lamps that only produce white light with a colour temperature of 2700k. These lamps can be dimmed and look like incandescent lamps. We ourselves use the Philips hue 806 lumens.⁸²

The white ambiance is a lamp that can produce different shades of white with a colour temperature between 2200k and 6500k. These lamps are suitable if you are not looking for coloured light but do want to create an atmosphere in your home. This is also the lamp we use.

Finally, you have the colour & white ambiance, these are the most elaborate lamps you can get from Philips Hue. These lamps can produce 16 million different colours. By combining these with a bridge you can take your lighting to another level.

6.7.3.3 Philips Hue Bridge⁸³

The Philips Hue bridge is the central point of the lighting system. This device receives and transmits information. It ensures the cooperation between your accessories and your lamps. The installation of the Philips hue bridge is very simple and can be done by anyone. After unpacking the

⁸⁰ <https://www.philips-hue.com/en-us>

⁸¹ <https://www.philips-hue.com/en-us/explore-hue/how-it-works>

⁸² <https://www.philips-hue.com/en-us/p/hue-white-ambiance-1-pack-e26/046677548490>

⁸³ <https://www.philips-hue.com/en-us/p/hue-bridge/046677458478>

bridge you connect it with a UTP cable to the router. After this, you plug the power cord into the power outlet and follow the installation instructions on the hue app on your smartphone or tablet. Installing the bridge is so easy that in most cases no technician is needed. We ourselves use the Hue bridge v2. This is the latest generation that can connect to Apple Homekit, allowing you to easily turn your home into a smart home. You can connect up to 50 Philips Hue lamps and accessories to one Hue Bridge. Using a Hue bridge is not necessary. The newest lights of Philips Hue now have Bluetooth, so you can control the lights directly with your smartphone. The disadvantage is that you are more limited than when you use a bridge.

6.7.3.4 D-Link smart plug

A smart plug turns an ordinary device into a smart one. This allows you to keep your current appliances if you want to create a smart home. You can control the power supply to the device via an app on your smartphone, it is also possible to automate the power supply.⁸⁴

The process to achieve this is quite simple, you can plug the smart plug into an ordinary socket after which you plug your device into the smart plug. Once you have done this you can download the manufacturer's app. Through this app you can access your smart plug. We use a smart plug of the brand D-Link.⁸⁵

6.8 Coding software

6.8.1 Home Assistant

Home Assistant is a free open-source software, which is designed as a home automation software to control various systems for smart home devices with a strong focus on local control and privacy. The software can be installed on various devices such as Odroid, Raspberry Pi, Intel NUC, Amazon Alexa Show and many more.⁸⁶ Afterwards it can be accessed via a web browser or an app for Android and iOS. The advantages of the software, apart from the high level of security due to local operation, are the countless add-ons. These allow services from major providers such as Apple, Samsung, and Spotify to be used on the Home Assistant. These and other add-ons created by the community make this software ideal for creating your own smart home. It supports common virtual assistants like Google Assistant or Amazon Alexa. There are also a lot of add-ons which can be installed free of charge. The most part of using the Home Assistant is coding with various computer languages and researching how to integrate each add-on. At the end every component can be displayed and controlled in a dashboard which indicates the chosen information. This can be seen on the following image:⁸⁷



Figure 53: Logo of Home Assistant

⁸⁴ <https://bit.ly/3bPS1Bv>

⁸⁵ <https://www.dlink.com/en/consumer/smart-plugs>

⁸⁶ <https://www.home-assistant.io/installation/>

⁸⁷ <https://demo.home-assistant.io/#/lovelace/0>

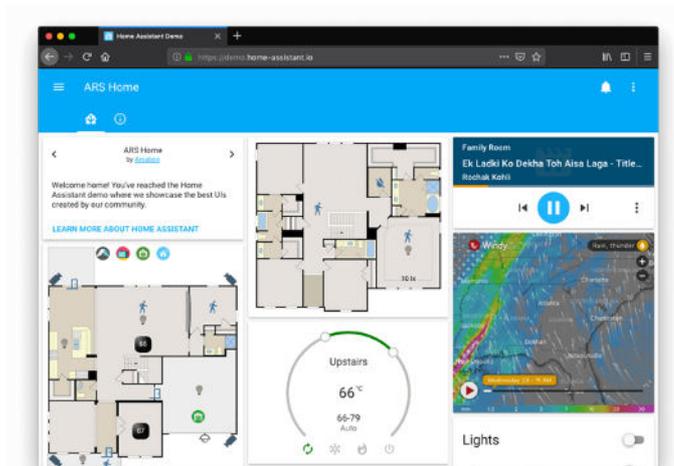


Figure 54: Demonstration of a Home Assistant display

6.8.1.1 Add-ons

As mentioned in the previous part there are a lot of add-ons available in the home assistant software. We have tested some of them and will now explain the problems, conveniences and errors. In the picture below are a few add-ons displayed. They can simply be installed via choosing them and following the procedure on the screen.

Official add-ons			
Almond The home server version of Almond	CEC Scanner Scan for HDMI CEC devices	Check Home Assistant configuration Check current Home Assistant configuration against a new version	deCONZ Control a Zigbee network with ConBee or RaspBee by Dresden Elektronik
DHCP server A simple DHCP server	Dnsmasq A simple DNS server	Duck DNS Free Dynamic DNS (DynDNS or DDNS) service with Let's Encrypt support	File editor Simple browser-based file editor for Home Assistant
Git pull Simple git pull to update the local configuration	Google Assistant SDK A virtual personal assistant developed by Google	Hey Ada! Voice assistant powered by Home Assistant	HomeMatic CCU HomeMatic: central based on OCCU
Let's Encrypt Manage certificate from Let's Encrypt	MariaDB A SQL database server	Mosquitto broker An Open Source MQTT broker	NGINX Home Assistant SSL proxy An SSL/TLS proxy
OpenZWave Control a ZWave network with Home Assistant	RPC Shutdown Shutdown Windows machines remotely	Samba share Expose Home Assistant folders with SMB/CIFS	TellStick TellStick and TellStick Duo service
Terminal & SSH Allow logging in remotely to Home Assistant using SSH	VLC Turn your device into a Media Player with VLC	Z-Wave JS Control a ZWave network with Home Assistant Z-Wave JS	

Figure 55: List of official add-ons

6.8.1.2 Node-RED

It is a programming tool (however some people call it a “programming environment”) which is mainly used to wire hardware devices, Application Programming Interface (API), and other online services in new and peculiar ways. It can be operated through a browser-based editor that facilitates making the connection between the devices. A wide range of different nodes that can be deployed to its runtime in a single click. Graphical flows and nodes are used by Node-RED, having individual components in a flow basically to create a program. Node-RED is used to create graphical programs called flows. Flows consist of nodes, which are rectangular objects seen in the example below. The language that is underlying Node-Red is JavaScript.⁸⁸

⁸⁸ <https://techexplorations.com/guides/esp32/node-red-esp32-project/1-introduction-to-node-red/>

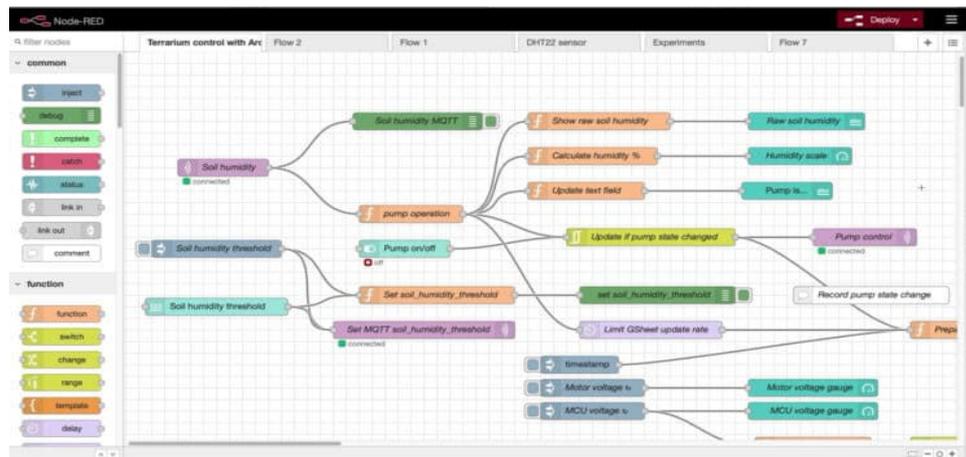


Figure 56: An example of use of Node-RED24

Node-RED does possess several built-in nodes, however, a user may decide to install additional third-party nodes. In Node-RED, the nodes can be easily assembled into configurations resulting in a useful program. Each node is pre-programmed to perform a specific operation, nevertheless, it is indeed possible to customize all the functions.⁸⁹

As mentioned before, JavaScript is the language of this environment and for this reason it is claimed to be “a very lightweight development environment and runtime environment”. This particular program is excellent for creating applications that are supposed to be “very nimble and very fast in their execution”, so they can run on low-cost hardware such as the Raspberry Pi. Node-RED is open source so every user may positively contribute to the development of this tool.

6.8.1.3 SSH & Web Terminal

The SSH & Web Terminal add-on gives us access to the Home Assistant terminal. This allows us to access the Raspberry Pi remotely and edit the Home Assistant software if necessary. If not installed, we would have to connect via Ethernet and be physically at the device. With this we can access it when in the same network. In general, we used this to set up the WIFI network and further settings of the network properties.

When in the same network we can simply connect to the system with the command “ssh careandconnect@10.80.5.9”. SSH is the acronym for Secure Shell and is for operating network services which are secured over an unsecured network.⁹⁰

⁸⁹ <https://techexplorations.com/guides/esp32/node-red-esp32-project/1-introduction-to-node-red/>

⁹⁰ https://en.wikipedia.org/wiki/Secure_Shell_Protocol

```

ege - root@a0d7b954-ssh:~ -- ssh careandconnect@10.80.5.9 - 131x36
Last login: Tue May 11 12:42:23 on tty900
ege@ege-mbp ~ % ssh careandconnect@10.80.5.9
The authenticity of host '10.80.5.9 (10.80.5.9)' can't be established.
ED25519 key fingerprint is SHA256:62+0wd39X6Cjus/VhajGatRlzSnPhd1/p0QcnUE+/tU.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '10.80.5.9' (ED25519) to the list of known hosts.
careandconnect@10.80.5.9's password:

Home Assistant

Welcome to the Home Assistant command line.

System information
IPV4 addresses for eth0:
IPV4 addresses for wlan0:

OS Version:          Home Assistant OS 5.13
Home Assistant Core: 2021.5.2

Home Assistant URL:  http://homeassistant.local:8123
Observer URL:        http://homeassistant.local:4357

```

Figure 57: Example of the terminal

6.8.1.4 Mosquitto broker

The Mosquitto broker add-on is an open-source broker that implements the MQTT protocol to the home assistant. Mosquitto is an easy solution for all low power computers to full servers. It provides a lightweight method of sending messages using a publish and subscribe model. The basic idea of Mosquitto is that you can subscribe and publish the topics in which the data will either be sent or received. Through the integration in Node-RED this makes the add-on suitable for IOT, embedded systems or microcontrollers. In the picture below you can see how the system is going to work. The sensors publish data to the Mosquitto broker which sends it to the home assistant and apps. On these apps the software Node-RED can process the given information and next steps can be taken in consideration.

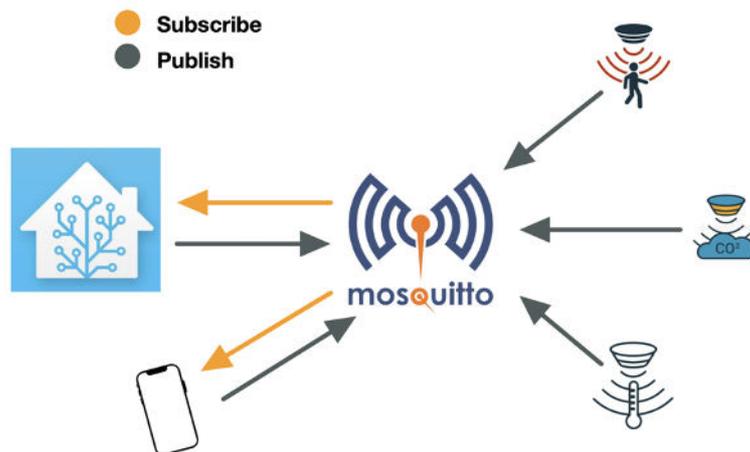


Figure 58: Example of Mosquitto and Home Assistant

6.8.1.5 DuckDNS

DuckDNS⁹¹ is a service which will point a DNS (Domain Name System) to an IP. By integrating this add-on, we can access the Home Assistant anywhere in the world. To do this, however, we need access to the router and other network information. We would make some changes in these, which are not accepted because they also affect other devices and users⁹². Therefore, we have taken a different route. We took advantage of a free trial period of a cloud service offered by the Home Assistant and the company Nabu Casa. All you have to do is follow the guide and the cloud service will be created automatically. After the test phase this service will cost 50€ per year⁹³.

6.8.1.6 ESPHome

ESPHome is an add-on, which allows us to control the ESP32 or ESP8266 and implement it in the Home Assistant⁹⁴. After installing, the ESP32/8266 has to be connected with the Raspberry Pi to establish a connection for the generated code. ESPHome has the feature that we don't need to write the code by ourselves. On the website are a lot of different sensors and devices which can be implemented, and the code is prewritten. Unfortunately, we cannot use this solution as we do not have access to the router. For our project we need static IP addresses that do not change and are assigned to the individual ESP32 (sensors). With the help of this add-on, everything could be displayed and controlled via the dashboard after programming.

6.8.2 Arduino

Arduino, an open-source platform consisting of a programmable circuit board (a microcontroller) and a piece of software, or IDE (Integrated Development Environment), can be easily run on the user's computer. The said software is utilized to write codes on the computer and upload them later on the Arduino board. Arduino IDE uses a simplified version of C++ coding language and therefore it is easier to learn how to program for someone who has never done it before. In our case we only used the Arduino software to program the ESP32. To load a code, you have to attach a USB cable via the PC to the ESP32 and upload it. After the upload we can look at the received data in a monitor.

The Internet of Things exceeds the Internet from connected computers to connected objects. Many elements can be connected to it such as applications, interfaces but also sensors. This system allows to access data and change settings from anywhere at any time. Today the IoT is applied to many sectors including healthcare. Raspberry Pi, which is often referred to as a pocket computer, is connected to the IoT and can be connected to a computer or a TV to observe the collected data. We can connect Node-RED to this Raspberry Pi to code and define the searched elements. We also utilize the ESP32 which is a microcontroller that can also be connected to the IoT. Finally, we have seen that Arduino is an open source that allows to program the different elements.

⁹¹ <https://www.duckdns.org>

⁹² <https://techtchandmoretech.com/guides/hass-duckdns/>

⁹³ <https://www.nabucasa.com>

⁹⁴ <https://esphome.io>

7. Marketing study

The realization of a marketing study is always interesting to do during the establishment of a project. It allows to better understand the environment a company is trying to reach and also to clearly define the targets and lines of action. Nevertheless, a marketing study is not fixed in time: it is in constant evolution with markets that change more or less quickly.

7.1 Objectives of the marketing study

The objectives of the marketing study are:

- Understand the project environment
- Define the target audience for the project
- Define the appropriate market
- Identify the industries that offer this type of service
- Define the strengths and weaknesses of the project

Analysing these study objectives will help answer the following question:

What services can be put in place to facilitate the life of the elderly and the caregivers with the help of sensors?

7.2 Methodology of data collection

The data that will be used for our study were first of all found on the internet, through marketing analysis, news, adapted material websites but also through concerned people (elderly people and medical staff).

In a first step, we selected the data according to their relevance: all articles dating after 2015 were favored to have the most recent information possible.

7.3 Targets and needs

Our project will focus on two main targets: the elderly people directly concerned by the implementation of such a device, and the nursing staff who accompany them in their daily lives. In order to know what elements to put in place we must first know our targets and their needs.

Elderly people

At what age is an elderly person?

The question is not so simple and there is no clear and defined average.

We consider that a person enters the world of seniors at the age of 60/65 years which is mainly based on retirement age and health insurance, but most people consider persons as an elderly at the age of 70.^{95,96}

⁹⁵ <https://elizz.com>

⁹⁶ <https://ec.europa.eu>

The population in Finland is getting older and older which means that the needs for the elderly will become more and more important. Finland is considered to have one of the oldest populations in Europe.⁹⁷

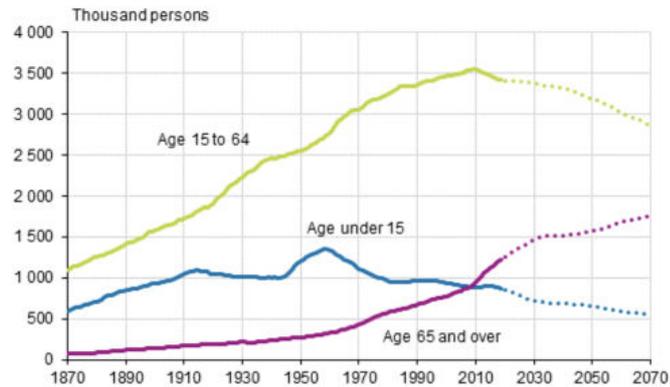


Figure 59: Projection of the evolution of population by age group⁹⁸

As we can see on this graph, the amount of people under 65 is decreasing whereas the number of people over 65 increases exponentially. The market around the elderly is therefore also in full expansion.

Elderly people represent almost 22% of the actual population:

	1900	1950	2000	2018	2019
Population, thousand					
Total	2 656	4 030	5 181	5 518	5 525
Males	1 311	1 926	2 529	2 723	2 728
Females	1 345	2 104	2 652	2 795	2 797
Age, %					
0–14	35,1	30,0	18,1	16,0	15,8
15–64	59,6	63,4	66,9	62,2	62,0
65–84	5,2	6,4	13,5	19,2	19,6
85–	0,1	0,2	1,5	2,7	2,7

Figure 60: Finish population from 1900 to 2019⁹⁹

⁹⁷ <https://thl.fi>

⁹⁸ <https://www.stat.fi>

⁹⁹ https://www.stat.fi/til/vaerak/index_en.html

It's also showed by this graph:

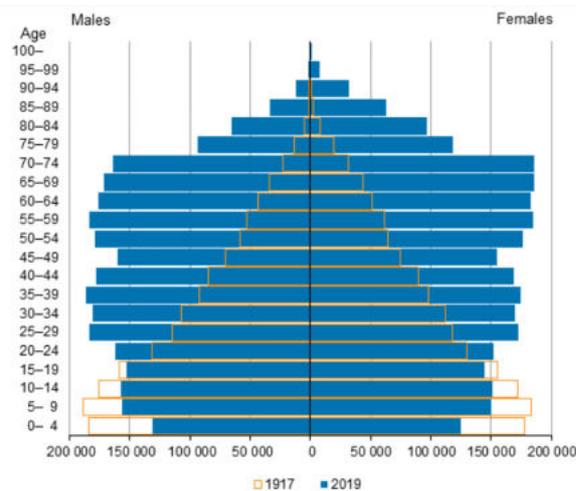


Figure 61: Dispersion of the Finnish population ⁸⁰

Plural research showed that the estimated number over 75 years old will be increased by 300 000 persons more by 2030. The forecasted increase in the age of the population is mainly due to the fact that life is getting easier and easier as the years go by, but especially due to the medical support.

On the one hand, the population is aging, but on the other hand, the elderly are living more and more alone in their homes, which requires special support.

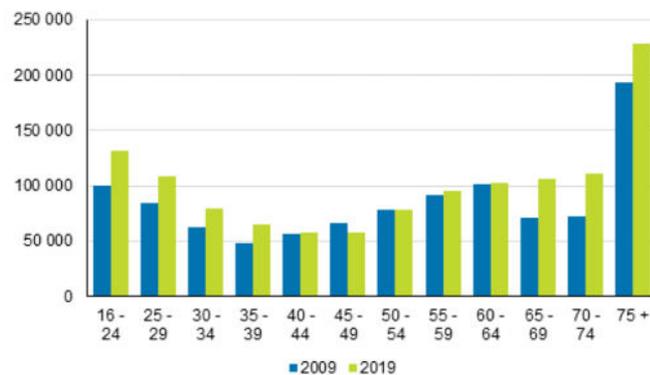


Figure 62: Graph of comparison of the number of persons living alone according to their age between 2009 and 2019¹⁰⁰

As we can see on this graph two main groups are living more and more alone. The students/young workers and the elderly. Contrary to retirement homes where the accompaniment is permanent, living alone represents more constraint; especially for an elderly person. And we have to take into account that these statistics only represent people living alone. The number of elderly couples still living together is also a large percentage of the population: thanks to the longer life expectancy people are widowed at a much later date; but their needs are the same as an alone living person.

In addition, nearly 90% of the population most at risk (people over 75) live alone.¹⁰¹ We can therefore conclude that a discreet sensor-based companion device is not silly to consider. On the

¹⁰⁰ https://www.stat.fi/til/asas/2019/asas_2019_2020-05-20_tie_001_en.html

¹⁰¹ Eveliina Ruth and Johanna Rautianinen Thesis "Senior Citizens Living Independently in Finland – Problem-Solving in a Group as a Resource for Maintaining Independent Living"

contrary, a very large part of the population is at risk at home and that these risks can easily be limited. It is important to note that social and healthcare spending per resident will continue to increase as the population ages, as more and more people will require ongoing support and home care.

Home Health Care is mainly based on services¹⁰² to help the person but also on care with nursing¹⁰³. It allows a person to maintain his or her independence by staying at home while providing support according to his or her needs. It's also called LTC: Long-Term Care.

It is also mentioned in several studies that with the increase of memory disorders due to age, enhanced housing services are also increasing¹⁰⁴. Almost 200 000 people are identified with Alzheimer nowadays. A patient with this disease who lives alone will need much more monitoring than the average person. Indeed, there may be forgetfulness about turning off the water, the person may forget to turn off the oven, ect. After the age of 65, nearly 50% of men and 40% of women end their lives without major illness. Nevertheless, many will have problems with arthritis, etc.¹⁰⁵

Among the diseases that affect and kill the most elderly people¹⁰⁶ are:

- Cancers¹⁰⁷, which can degrade vital organs and therefore requires increased surveillance. The risk increases more and more with the increase in life expectancy (the main ones are prostate, lung, colon and breast cancer)
- Alzheimer's¹⁰⁸ disease, which will cause some people to put themselves at risk because of the disease (nearly 85,000 patients have severe dementia and 35,000 have moderate dementia in Finland)
- Parkinson's¹⁰⁹ disease (affects about 2% of the population). It is the second most common neurodegenerative disease after Alzheimer's disease.
- Osteoarthritis¹¹⁰ (affects nearly 60% of the population over 65 years old) which makes it difficult and painful to move and can lead to falls
- Eye diseases, especially Age-related macular degeneration (AMD)¹¹¹, which causes significant vision problems and prevents people from perceiving their environment correctly

Senior people living alone are most vulnerable to accidents, particularly in and around the home. The goal is to determine what the main risks are and how to prevent or overcome them, but also address the common hazards in homes and make family and senior people understand which hazards lay around their room.

¹⁰² <https://www.files.ethz.ch/isn/122399/Finland.pdf>

¹⁰³ <https://www.medicare.gov/what-medicare-covers/whats-home-health-care>

¹⁰⁴ <https://bit.ly/3vcQqG>

¹⁰⁵ https://www.euro.who.int/__data/assets/pdf_file/0011/355979/Health-Profile-Finland-Eng.pdf

¹⁰⁶ <https://soin-palliatif.org/seniors/maladies-age/>

¹⁰⁷ <https://www.cancersociety.fi/publications/reports/cancer-in-finland-2016/cancers-after-the-age-of-75/>

¹⁰⁸ FINNISHMEDICAL JOURNAL Supplement 10/2008 Panel of experts set up by the Finnish Alzheimer's Disease Research Society: Jaana Suhonen, Kari Alhainen, Ulla Eloniemi-Sulkava, Pirjo Juhela, Kati Juva, Minna Löppönen, Markku Makkonen, Matti Mäkelä, Tuula Pirttilä, Kaisu Pitkälä, Anne Remes, Raimo Sulkava, Petteri Viramo, Timo Erkinjuntti

¹⁰⁹ <https://bit.ly/348yLuQ>

¹¹⁰ <https://bit.ly/348yLuQ>

¹¹¹ <https://preventblindness.org/amd-age-related-macular-degeneration/>

7.3.1.1 Main risks

The main 5 risks are **falling, poisoning, fires, burns and scalds** and **hypothermia**.

7.3.1.1.1 Falling

Falling is by far one of the leading causes of injury in the senior population and many of these accidents happen in their own home. In fact, 60 to 70 percent of these accidents happen in their own home^{112,113}. The causes of a fall are often multifactorial involving both environment hazards as underlying health problems such as physical changes of aging: decline in hearing and vision, bone density loss, balance issues and many more.

Risk factors for falls:

- Physical ability and lack of mobility, balance and gait disorders
- Nutritional status - vitamin D and calcium deficiency
- Medication - analgesics, antidepressants etc.
- Acute and chronic diseases and disorders including stroke and heart disease
- Environmental hazards (explained below)
- Hip fractures
- Fractures, particularly hip fractures are one of the most debilitating results of an accidental fall. Ninety per cent of hip fractures occur among those aged 50 and over.
- Hip fracture is a major cause of morbidity and mortality. It can result in medical complications, infections, blood clot in the leg and failure to regain mobility.

7.3.1.1.2 Poisoning

Poisoning happens accidentally and in several ways, the main risk is by taking too many different medications while there can also be the risk of inhaling toxic gasses such carbon dioxide from stoves, carbon monoxide and pipeline gasses. To avoid these kinds of risks the fueled burning devices should be checked regularly, chimneys and flues should be checked yearly, and the medication should be checked by the doctors plus kept in an organized and labelled way.

7.3.1.1.3 Fire

Fire is a risk in any home and should at all times be managed with care. Fires in senior people's homes should be discouraged but even then, they still happen.

To prevent these kinds of accidents it's advised not to smoke in bed, fit fire guards on stoves or fireplaces, use electric blankets correctly and get them checked regularly, fit smoke detectors with ten-year battery lives and do not dry clothes or any other flammable materials on stoves or heaters.

7.3.1.1.4 Burns and scalds

Contact burns or scalds to senior people can prove to be fatal. This due to being frail and of poor health, these conditions of the senior victim are often contributing factors. The main sources of

¹¹² <https://www.greatcall.com/resources/falls/elderly-falls-statistics>

¹¹³ <https://www.athomehealth.org/blog/2017/march/5-in-home-safety-risks-for-seniors/>

contact burns are radiators, electric fires, stoves, fireplaces and cookers. Many are scald injuries, involving the use of kettles.

To prevent these kinds of injuries the temperature of water to the bathtub should be limited to 46° C, fitting thermostatic mixing valves, the use wall mounted coiled heaters instead of kettles and a fireguard for the stove, fireguard and heaters.

7.3.1.1.5 Hypothermia

Hypothermia happens when the body temperature drops to 35° C. The cost of providing adequate heating in winter is undoubtedly an important factor. To prevent this it's advised to eat, drink and move regularly, wear multiple layers of clothing but mostly keep your house temperature at a constant temperature.

Some other risks are considered important such as lack of ventilation, poor air quality, too much humidity, the risk of gas leakage and therefore of explosion (many elderly people have gas stoves).

Environmental hazards¹¹⁴:

- General household:
 - Poor lighting (too dim)
 - Lighting too bright
 - Light switches hard to reach/find
 - No night light(s)
 - Carpets/floor coverings torn or in poor condition
 - Rugs that slip
 - Slippery floors Furniture or clutter obstructing walkways
 - Cupboards/shelves too high
 - Cupboards/shelves too low
 - Taps hard to reach or to turn on/off
 - Unstable chairs or tables
 - Chairs without armrests or with low backs
 - Extension cords across walkways Unsafe electrical appliances
- Kitchen
 - Dials on stove difficult to see
- Bathroom/toilet/laundry
 - Bathtub/shower recess slippery
 - Bathtub/shower recess without grab rails
 - Soap, shampoo, etc. not accessible
 - Hob on shower recess
 - Glass doors not safety glass
 - Medicine cabinet poorly lit
 - Toilet without grab rails

¹¹⁴<https://bit.ly/3hNif6K>

- Toilet seat too low
- Toilet -with inward opening door
- Location of toilet in house
- Toilet located outside

- Stairs
 - Too long In need of repair
 - Step edges hard to see
 - Proper handrails not present
 - Handrails unstable or not secured
 - Handrails not long enough
 - Inadequate lighting

- Outside
 - Too steep
 - Sloping, slippery, obstructed or uneven pathways
 - Steps, landings, verandas, patios or entrances slippery when wet

It is therefore necessary to rethink the current house and make it help the daily life of the elderly. This is where the sensors we are trying to put in place come into play: in case of a problem, an alert will be given (fall, fire, etc.) and will directly inform the competent people; this redesigned house will also help the inhabitant with a medicine dispenser, light signals to inform of risks, etc. The goal is to make the accompaniment and care of these people fun, simple and accessible. This could also avoid the abuse of some structures (which is mainly due to the lack of personnel who must take care of more and more patients because of the aging population) that do not take enough care of people and whose families find their elders "hungry and thirsty, laying in her own urine-soaked bed sheets"¹¹⁵ and be sure to have a good follow-up of the loved one. Safety of the person as well as safety around good care.

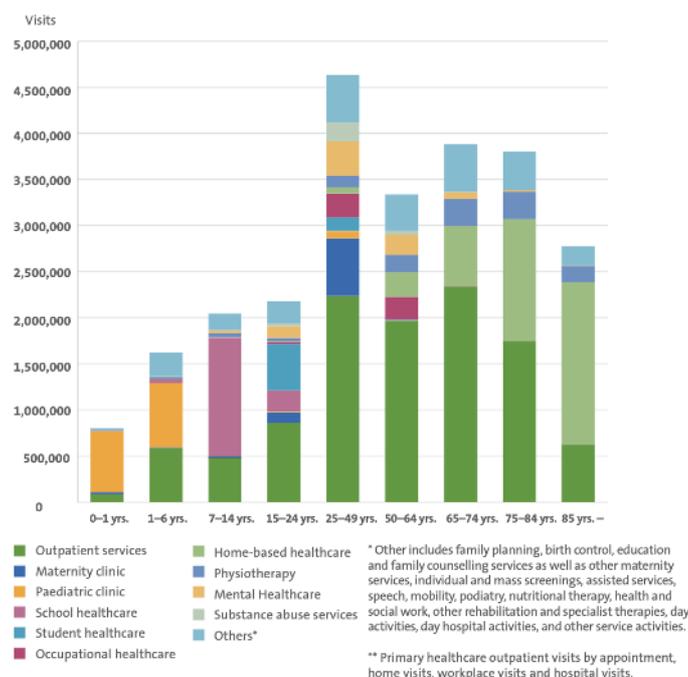


Figure 63: Graph of the number of visits for different types of cars according to the age⁸⁶

¹¹⁵ <https://newsnowfinland.fi/editors-pick/finlands-elderly-care-crisis> (2017)

The over 65 population has nearly 4 million of home-based healthcare visits per year in 2018 knowing that the need is constantly increasing. Unfortunately, an aging population also means more care and monitoring. That's why we conducted a survey that we sent to the elderly to understand their needs but also their fears regarding these new technological tools.

Within the survey we asked important questions for elderly people and also caretakers. The questions asked in the survey¹¹⁶ were :

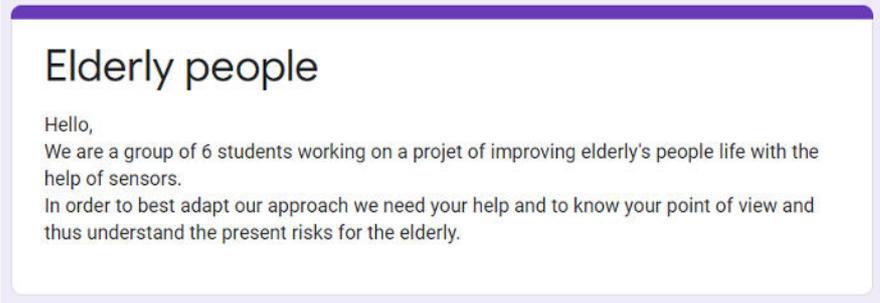


Figure 64: Survey questions (1)

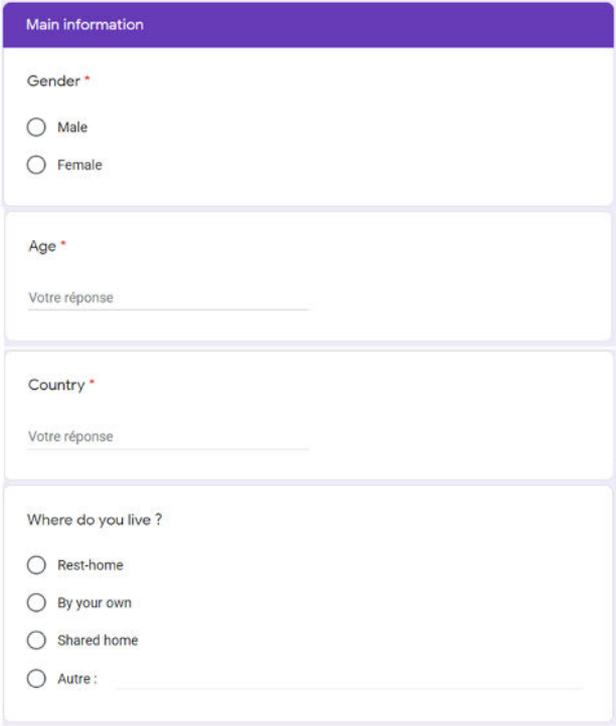
A screenshot of a survey form titled "Main information". It contains four sections: 1. "Gender *" with radio buttons for "Male" and "Female". 2. "Age *" with a text input field labeled "Votre réponse". 3. "Country *" with a text input field labeled "Votre réponse". 4. "Where do you live ?" with radio buttons for "Rest-home", "By your own", "Shared home", and "Autre :", followed by a text input field.

Figure 65: Survey questions (2)

¹¹⁶<https://bit.ly/3yyfPDp>

Questions

What are the main problems you may encounter in your daily life? *

Votre réponse _____

Our goal is to integrate sensors that can make life easier for the elderly person and the caregiver when it comes to caring for the elderly. For this purpose we are studying how to integrate sensors and in what way. For example, an infrared sensor could highlight a fall, a smoke sensor a potential start of a fire etc. These will be connected to an application that can be used by the nursing staff to have a follow-up. Have you ever worked with sensors? *

Yes

No

Figure 66: Survey questions (3)

YES	NO
<p>Going further about sensors</p> <p>What are your experiences ? For exemple, how often do the sensors report a false alarms ? *</p> <p>Votre réponse _____</p>	
<p>Sensors</p> <p>Would you be willing to let sensors in your life ? *</p> <p><input type="radio"/> Yes</p> <p><input type="radio"/> No</p>	
YES	NO

Yes	No
<p>Which sensors would you be willing to let in your life ? *</p> <ul style="list-style-type: none"> <input type="checkbox"/> Infrared, detects a person in a room and permit to alert if someone falls <input type="checkbox"/> Monoxide, detects a gas leak <input type="checkbox"/> Humidity, measures the amount of water vapor <input type="checkbox"/> Motion sensor, detects unwanted movement <input type="checkbox"/> Camera, visual monitoring of any falling ; could alert if something unusual happens <input type="checkbox"/> Sounds, could detect good breath during sleeping <input type="checkbox"/> Voice activated device, for example tuning on the light with the voice <input type="checkbox"/> Pressure, detects weight and if a pressure is maintained for too long (=problem) <input type="checkbox"/> Emergency button (somewhere in the house) <input type="checkbox"/> Draw-on-skin sensor, it's temporary, monitor the parameters linked to you sweat (=health information) <input type="checkbox"/> Bracelet/watch sensor which can monitor the health of the person 	<p>If none, why ?</p> <p>Votre réponse</p> <hr/> <p>For exemple those kind of sensors could be used : Infrared, detects a person in a room and permit to alert if someone falls, monoxide, detects a gas leak, humidity, measures the amount of water vapor, motion sensor, detects unwanted movement, camera, visual monitoring of any falling ; could alert if something unusual happens, sounds, could detect good breath during sleeping, voice activated device, for example tuning on the light with the voice, ressure, detects weight and if a pressure is maintained for too long (=problem), emergency button (somewhere in the house), draw-on-skin sensor, it's temporary, monitor the parameters linked to you sweat (=health information), Bracelet/watch sensor which can monitor the health of the person. Do you still don't want to let some of them let in your life ?</p> <p><input type="radio"/> Yes</p> <p><input type="radio"/> No</p>
<div style="background-color: #4a4a8a; color: white; padding: 5px; border-radius: 5px;">Further questions</div> <p>Would you agree to use a tablet or a smartphone to improve your daily life, prevent risks and alert with the app ? *</p> <ul style="list-style-type: none"> <input type="checkbox"/> Yes for a tablet <input type="checkbox"/> Yes for a smartphone <input type="checkbox"/> Yes for a computer <input type="checkbox"/> No for all <p>If no, why ?</p> <p>Votre réponse</p> <hr/> <p>Any comment ? *</p> <p>Votre réponse</p>	

Figure 67: Path of survey questions

It was translated and sent to each of the countries of the project members to understand the different perceptions according to the cultures but also to know if some countries are more advanced than others in this field. According to different studies and articles used in that report we have been able to understand that the main risks encountered by elderly people in their homes are falling, poisoning, burns and scalds, hypothermia, gas leak, bad air quality.

The results from the survey are based on French population because it was the only country from which the results were obtained. This survey is not representative as it only reaches one country and a small representative group. Nevertheless, it does give an idea of the fears and expectations.

65% of responses were given by women and 35% by men on a panel ranging from 60 to 90 years old. 33% of respondents live alone, 67% live with their spouse. Only 25% of them have ever been confronted with sensors in their daily life. (Panel of 27 people)

The main problems encountered in everyday life by these people are small daily tasks such as carrying heavy objects and housework. It is also possible to find the difficulty to stay connected with the actual and active world; the lack of social life, the difficulty to take medical appointments. We also find the fear of falling which occupies the thoughts of the elderly. Finally, a person with Alzheimer's disease said that the main difficulty for her was to find her way around her house.

People who had already been in contact with sensors used bracelets/necklaces with alarm buttons connected to monitoring centers. Only a few tiny false alarms were given (< 3).

As time goes by more and more people are willing to let sensors into their lives, according to our survey about 70% if it could help them improve their daily life.

Sensors are ranked here in order of preference:

- 1) Bracelet that tracks the health of the person and informs about shocks
- 2) - Emergency button somewhere in the house
 - voice-activated device for light
 - Infrared devices that highlight a person in a room or a fall
 - water leak sensor
 - air quality analysis sensor
- 3) Carbon monoxide sensor
- 4) - Surveillance camera to detect a fall
 - Sound/microphone system to verify that the person is breathing properly during sleep
- 5) - Full floor pressure sensor to detect if a person falls
 - Drawing on the skin with a sensor ink that allows to analyze the perspiration and bring data on health
- 6) Humidity sensor

The people for whom the implementation of sensors is not useful explained that it was because they still felt independent (75% of those who are against sensors) or that the presence seemed too intrusive (25% of those who are against sensors).

Nevertheless, by explaining the situation to these people and showing them how sensors can be useful 80% change their mind and say they feel ready to welcome sensors if it is for their health. Finally, only 18% of people do not want to use a tablet, computer or smartphone to improve their daily life, prevent risks and launch alerts via an application. For the remaining 82%, there are 50% in favor of a tablet, 44% in favor of a computer and 38% in favor of a smartphone (multiple answers possible).

If a surface has to be used, the tablet should be favored.

Finally, we asked the different respondents what they thought of this project after all these questions and all the explanations given. The feedback was very instructive. The majority of the population is open to the idea of integrating sensors in their homes, with answers such as "a very good way to age well at home", "I would appreciate having sensors that could simplify my life and my daily life in my home", "very good for people living alone with reduced capacities", "brings security and a reassuring 'presence'", or some people who still have difficulty seeing all that this system can bring them.

However, on one side (a minority of people), there is a fear of being monitored and on the other hand (the vast majority), a population that is open to these changes if they can improve their daily lives and reassure them.

7.4 HealthCare

Who is part of the healthcare field?

This concerns a lot of people. It includes professionals such as nurses, dentists, psychologists, physicians, physiotherapists, community health workers and all personnel who may be involved in the care and support of a person.

Here nurses will be the main target in this field as the simulation room has been created for them. Nevertheless, all the devices thought within the project are applicable and usable by all the professions in the absolute. Indeed, in an idyllic way and in order to accompany the patient in the best way, each of the members surrounding an elderly person should have access to this information (in due time and with the agreement of the patient).

In 2016 there were nearly 61 207¹¹⁷ nurses in Finland.

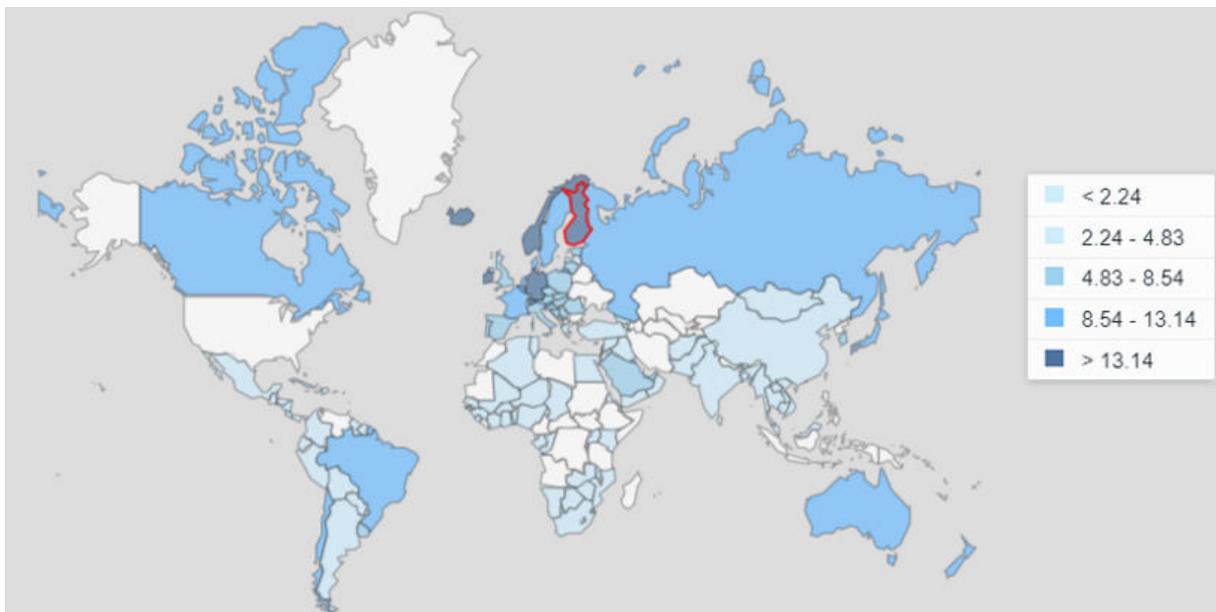


Figure 68: Number of nurses and midwives per 1000 people in the world

Finland (here highlighted with red borders) is one of the best supported countries in terms of health with more than 13.4 nurses per 1000 inhabitants.

¹¹⁷<https://bit.ly/3bMTGHV>

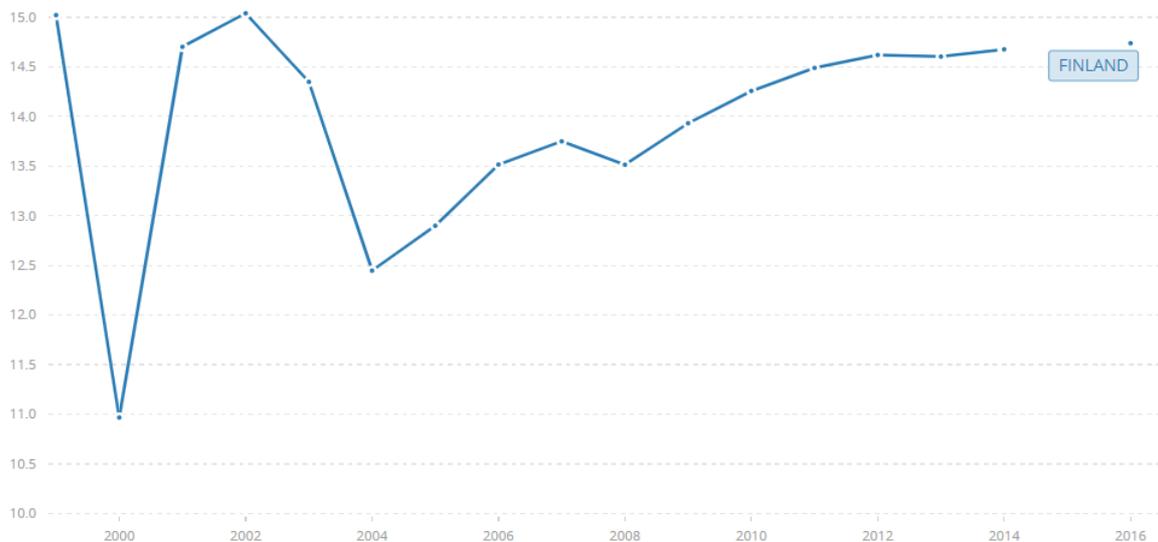


Figure 69: Number of nurses and midwives per 1000 people in Finland¹¹⁸

The number of nurses has increased significantly over the last few years until it has reached a plateau. It may be enough to fulfill the needs of the population, but the problem is that these have changed. Indeed, the population is ageing rapidly, so the need for care and support is increasing to the point that the profession is unfortunately losing its social function. Nurses have less and less time to perform their tasks because they have more and more patients to take care of. Among these tasks there is of course the care but also the control of elements that take time. These last ones are actions made by man which could be replaced by sensors to save time, even if only on the action or the control. For example, monitoring that the treatment has not been forgotten with a medication dispenser.

That is why we did a survey to understand what their difficulties and needs are and what solutions the project could bring.

The questions in the survey are the following ones:

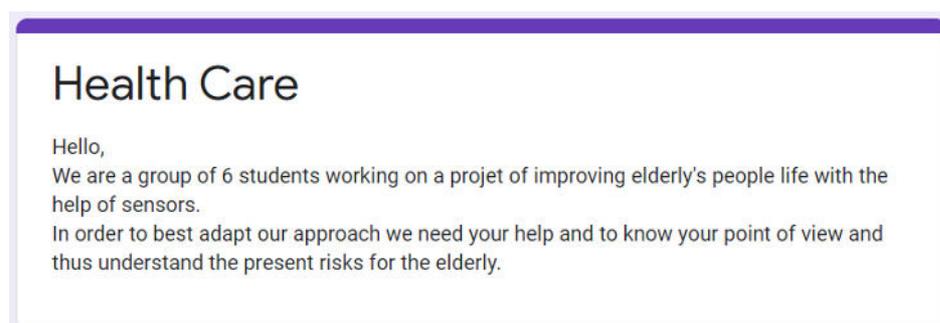


Figure 70: Survey questions (1)

¹¹⁸ <https://bit.ly/3yAE3xc>

Health Care

*Obligatoire

Main information

Gender *

Male

Female

Age *

Votre réponse _____

Country *

Votre réponse _____

Occupation *

Votre réponse _____

Figure 71: Survey questions (2)

Questions

What are the technical resources you currently use to take care of elderly people ? *

Votre réponse _____

Our goal is to integrate sensors that can make life easier for the elderly person and the caregiver when it comes to caring for the elderly. For this purpose we are studying how to integrate sensors and in what way. For example, an infrared sensor could highlight a fall, a smoke sensor a potential start of a fire etc. These will be connected to an application that can be used by the nursing staff to have a follow-up. Have you ever worked with sensors ? *

Yes

No

Figure 72: Survey questions (3)

YES	NO
<div data-bbox="373 385 1094 620"> <p>Going further about sensors</p> <p>What are your experiences ? For exemple, how often do the sensors report a false alarms ? *</p> <p>Votre réponse _____</p> </div>	
<div data-bbox="373 651 1222 1919"> <p>Sensors</p> <p>What are the main risks for elderly people ?</p> <p>Votre réponse _____</p> <p>What rooms HAVE to be covered by sensors ? *</p> <ul style="list-style-type: none"> <input type="checkbox"/> Bedroom <input type="checkbox"/> Livingroom <input type="checkbox"/> Bathroom <input type="checkbox"/> Toilets <input type="checkbox"/> Kitchen <input type="checkbox"/> Hallway <input type="checkbox"/> Garage <input type="checkbox"/> Stairs <input type="checkbox"/> Veranda <input type="checkbox"/> Autre : _____ <p>To help you working with elderly people and taking care of them, what feature would you really need on the app ? Schedule agenda for nursing/cleaning etc ; health car evolution ... *</p> <p>Votre réponse _____</p> <p>Any comment ? *</p> <p>Votre réponse _____</p> </div>	

Figure 73: Table of the different steps of the survey

As for the elderly's survey, the results are based on French population because it was the only country from which we had the results. This survey is not representative as it only reaches one country and a small panel. Nevertheless, it gives an idea of the fears and expectations.

All the people interviewed were women in their twenties from France, all nurses. (Panel of 18 people)

The main tools used to take care of the elderly are bell systems, air mattresses to avoid skin alteration, devices to help walking and getting up. Nevertheless, none of the nurses in question have ever been in contact with sensors.

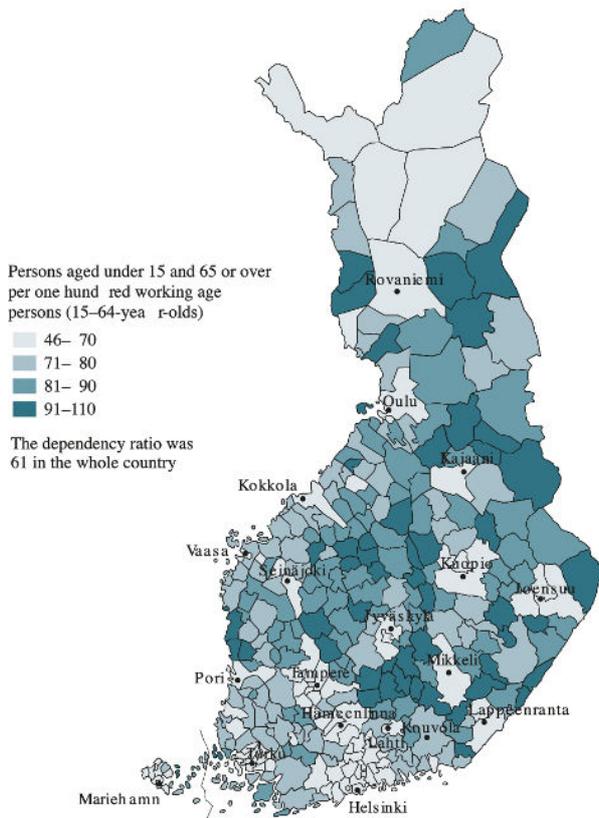
For these professionals, the main risks for elderly people are falls, malnutrition, balance and walking disorders, visual disorders, skin alterations, loss of autonomy, swallowing disorders that can lead to choking, loss of space-time references, but also social and family isolation.

For these nurses, the rooms that contain the highest risks for elderly people are:

- the bedroom
- the living room
- the bathroom
- the toilets
- the kitchen
- the stairs
- the corridors
- garages
- verandas

Finally, for them the elements to possibly include in the application are the follow-up of appointments, the living/dietary habits, the degree of autonomy, the persons to contact in case of emergency, the name and coordinates of the attending physician and the specialists who follow the patient, the type of housing, if the person lives alone or not, the medical history and allergy. These solutions would possibly facilitate the link between a caregiver and a patient.

7.5 Sensors market



Regional division as on 1 January 2020

Figure 74: Map of the repartition of the population in Finland¹¹³

Therefore, it is necessary to find a way to take care of them from a distance as long as adequate structures cannot be found nearby. Today, the cost for LTC is about 2559 million euros¹¹⁹ and a part of his money is mainly to watch out after people and check that everything is okay. A device with sensors can therefore only be beneficial.

7.5.1 Existing companies

In the world:

Qorvo

Researching companies: STMicroelectronics¹²⁰

QORVO

Figure 75: Logo of QORVO

Objectives: define and analyze the current situation as well as the characteristics of the products and services we can offer in order to understand what can distinguish us from the competition.

It should be noted that the number and the types of home health care providers on the one hand vary in function of the region and on the other hand are decreasing over time. This poses a problem when the needs are in reverse trend and keep increasing.

And even more so, single seniors tend to live far from major cities and therefore from major care centers.

¹¹⁹ files.ethz.ch/isn/122399/Finland.pdf

¹²⁰ <https://bit.ly/2QJZ5lw>

Qorvo's^{121,122,123} Senior Lifestyle System has been tested and utilized over the last 15 years in health networks in Europe, this system has been created to help seniors live more autonomously.

The company offers small, discrete sensors that send alerts when there are unusual events or changes in the behaviour of the person or items being studied. They will have a learning period on the lifestyle of the inhabitant and their habits (we find information on eating habits, sleep cycle with the time of waking up, walking speed, etc.) to be able to launch alerts to the family in case of significant changes.

The sensors (motion detection as well as door/closing sensors) are connected to ZigBee which is used to retrieve and process the information. Using this network allows to avoid interfering with other radio frequencies of the devices in the house.

The cost of this system is \$100 for installation and a subscription of \$20 to \$30 per month that allows the use of the network set up and gives the right to maintenance in case of damaged or non-functioning equipment.

Today there are nearly 3000 seniors equipped with this system in the Netherlands and a turnover of nearly 3.2 billion dollars in which their costs for goods were 1.9 billion dollars. What provided a gross profit of 1.3 billion dollars.

BeClose with Amada Senior care¹²⁴



Figure 76: Logo of Amada Senior Care

It is an American company that provides non-medical care and support to seniors in their homes. The goal is to set up a follow-up of the persons as with the service "Caregiver". This service consists in providing the senior with a caregiver to come to his home to take care of them, to check that there is no problem with the person and his home, to have a psychological support and to help him in his daily tasks.

Amada Senior Care also offers the "Emergency response system" service, which is a 24/7 surveillance to reassure families. Among these monitoring systems is the BeClose device, a set of connected sensors (carpet pressure sensor, door sensor, motion sensor, etc.) that send an alert in case of problem.

Because it is a Franchise with over 100 companies, it is difficult to estimate their revenue. However, according to "Growjo"¹²⁵ it is estimated at about 189,9 M\$, which is about 161M euros.

In Finland:

Throughout the years the development of the IoT sector has been very rapid. More and more businesses and startups are based on IoT solutions and technology. Being involved in the project

¹²¹ <https://www.qorvo.com/design-hub/blog/smart-homes-for-seniors-how-iot-helps-aging-parents>

¹²² <https://bit.ly/3v7jW7v>

¹²³ <file:///C:/Users/Jim/Downloads/qorvo-senior-lifestyle-system-brochure.pdf>

¹²⁴ <https://www.amadaseniorcare.com/>

¹²⁵ <https://bit.ly/3vfi7p3>

strictly connected with IoT and sensors, the knowledge about possible competition in Finland is of great importance. Below are presented some examples of businesses, projects, and startups that can revolve around IoT and can be considered as the competition for Care & Connect.

Please note that all sales figures reported included all areas of company activity, not just those focused on technology applied to health.

Bittium



Figure 77: Logo of Bittium

Bittium¹²⁶ is a Finnish company with headquarters in Oulu. They offer many solutions such as systems and platforms for phones and computers to ensure data and network security, but also more technologically advanced products about health. We find services that allow us to measure bio signals in cardiology or neurology. They also offer data analysis systems for sports medicine or occupational medicine.

The company is divided into 4 main areas: "Tactical Communications", "Secure Communications & Connectivity", "R&D Services" and "Medical Technologies". It is on this last point that we will focus. Today, Bittium generates nearly 78.4 million euros in sales. In this axis, their three major areas of competence and expertise.

Cardiology¹²⁷: they have created devices capable of revealing cardiac anomalies. Once detected, it is analysed in order to make suggestions to the cardiologist in charge of the patient. Once the anomaly is treated, the device can be used to follow up the patient.

Neuroscience and neurophysiology¹²⁸: the system based on a strip of electrodes is designed to diagnose and analyse epileptic seizures or various cerebral accidents. It can be used upstream to study the state of the brain or throughout the process of treatment and recovery of the patient to see the evolutions.

Sleep apnea¹²⁹: these breathing disorders appear when we sleep and can create serious health concerns if not treated in time. The proposed device is a device that records respiratory fluctuations to highlight the various concerns encountered.

Bittium therefore proposes mostly connected devices created with their own lines of code rather than a health information network. For the moment they are not designed to be connected to a network to exchange data remotely but more as a local solution that the doctor can analyse afterwards.

Noona

¹²⁶ <https://www.bittium.com>

¹²⁷ <https://www.bittium.com/medical/cardiology>

¹²⁸ <https://www.bittium.com/medical/neuroscience-neurophysiology>

¹²⁹ <https://www.bittium.com/medical/bittium-respiro>



Figure 78: Logo of Noona

The headquarters of Noona is situated in Helsinki. Their annual sales¹³⁰ are close to 7 million dollars per year, or about 5,750,000 euros. Noona¹³¹ is a company specialized in oncology. That is to say that they are specialized in the treatment of cancers.

They have established an intelligent service accessible on cell phones for health care staff and more specifically for nurses who provide daily care. The service collects data on the patient's condition and the evolution of these results. This allows the nursing staff to anticipate the care to be practiced or the possible complications and relapses. The care then becomes an active care, i.e. they take advantage of the results by extrapolating and anticipating them, which allows a more effective accompaniment. In the long term, this allows for a significant reduction in the number and length of hospitalizations as well as emergency room visits.

Studies conducted by the company estimate that the implementation of these devices have allowed patients with these diseases to gain several months of life as well as less painful ailments. Depending on the evolution of the disease, caregivers can request daily or weekly monitoring. In addition to indicating the periods that will require more care, this system also makes it possible to adapt and optimize the dosage of the medicines according to the need and the duration during which they must be given, thus limiting toxicity.¹³²



Figure 79: Missions fulfilled by Noona

Fibion



Figure 80: Logo of Fibion

Fibion headquarter is situated at Jyväskylä. Their sales revenue¹³³ is about 4 million dollars, about 3 300 000 euros. Fibion¹³⁴ is a company specialized in physical activity analysis¹³⁵. It is integrated

¹³⁰ https://rocketreach.co/noona-healthcare-profile_b5fae6dcf6ac0a73

¹³¹ <http://www.noona.com/>

¹³² <https://www.varian.com/fi/products/software/care-management/noona>

¹³³ <https://bit.ly/3oO3ff6>

¹³⁴ <https://fibion.com/en/>

¹³⁵ <https://www.phlu.fi/buusti360/buusti360-palvelut/fibion-aktiivisuusmittaus/>

in this panel of companies around health because it has a use that can be interesting in the field of health and monitoring of people.

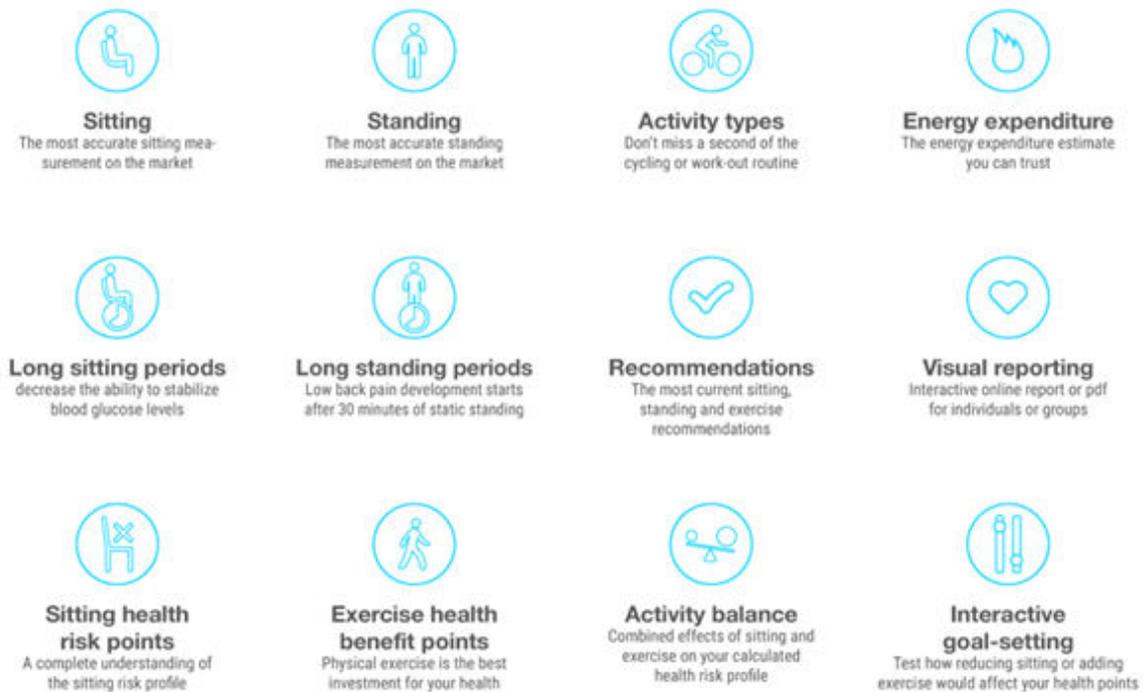


Figure 81: Parameters considered in the analysis of physical health

It detects sitting and standing activities as well as more or less intense sports activities (walking or running, etc.). The prices of this motion sensor that you attach to your wrist or thigh are as follows:

FIBION PRICE LIST

Get Started! Fibion 1 plus 2 298 € 

Buy Fibion Reports 

# of Reports	Discount %	Report Unit Price	Total
1	0%	29,00	29
10	-5,00%	27,55	276
20	-10,00%	26,10	522
30	-12,50%	25,38	761
40	-15,00%	24,65	986
50	-16,25%	24,29	1.214
60	-17,50%	23,93	1.436
80	-20,00%	23,20	1.860
160	-25,00%	21,75	3.480

Buy Fibion Equipment Packages 

# of Fibion	Discount %	Fibion Unit Price	Total
1	0%	240,00	240
10	-10,00%	216,00	2.160
20	-15,00%	204,00	4.080
30	-17,50%	198,00	5.940
40	-20,00%	192,00	7.680
50	-21,25%	189,00	9.450
60	-22,50%	186,00	11.160
80	-25,00%	180,00	14.400
160	-30,00%	168,00	26.880

Figure 82: Prices of Fibion devices¹³⁶

¹³⁶ https://fibion.com/en/store/pdf/Fibion_Price_List_EN_2016-08.pdf

Atostek



Figure 83: Logo of Atostek

Atostek headquarter is situated in Tampere and their annual sales revenues are about 9,2 million dollars (about 7,6 million euros).¹³⁷ Atostek is a company specializing in two areas:

- Autonomous Machines and Vehicles
- E-Health and e-social

In the field of health, Atostek offers a global platform to pool all prescriptions, medical records with medical procedures and medical history as well as social welfare information. It has existed since 2015. For this, two solutions¹³⁸ are available:

- Recibus
- Clinibus

Recibus, which has been in existence for nearly 5 years, is the platform that makes available and gathers all the different electronic prescriptions made by the entire medical profession. It is coded on the cloud which allows access to these data at any time and any place as long as one has the authorizations. In addition to collecting this data, it also contains advice on prescriptions with different indications to allow patients to have a reminder if they no longer know how often and how they should take their medication. This information is also accessible to pharmacies to control that there are not more purchases than usual with the same prescription.

Clinibus is a National Cross-organisational Health Record platform that has been in existence for almost 6 years. Clinibus completes Recibus with the creation and updating of medical records. That is to say, on one side we find Recibus which is the platform created for the prescriptions and on the other side there is Clinibus with all the information on the medical appointments, the background information, the list of doctors who follow the patients, the medical acts carried out...

All this data is obviously protected with a highly secure cloud (due to the sensitivity of the information) and because of this fact, it is completely independent of any structure (public or private). Nevertheless, it can be used without apprehension by the latter by being connected to their network and by assigning access keys that ensure security.

¹³⁷ <https://bit.ly/3wrqNJ7>

¹³⁸ <https://www.businessfinland.fi/en/companies/a/atostek-oy>

Usability

The user interface is designed to be simple so that it is quick to learn and easy to use. Patient records and entire prescription history are visible with one glance.

From physician's point of view:

- The physician can create, renew and cancel prescriptions together with viewing patient's medication history.

From pharmacist's point of view:

- The pharmacist can dispense a prescription and view patient's medication history.

From patient's point of view

- The patient only needs to prove their identity to the physician and pharmacist.

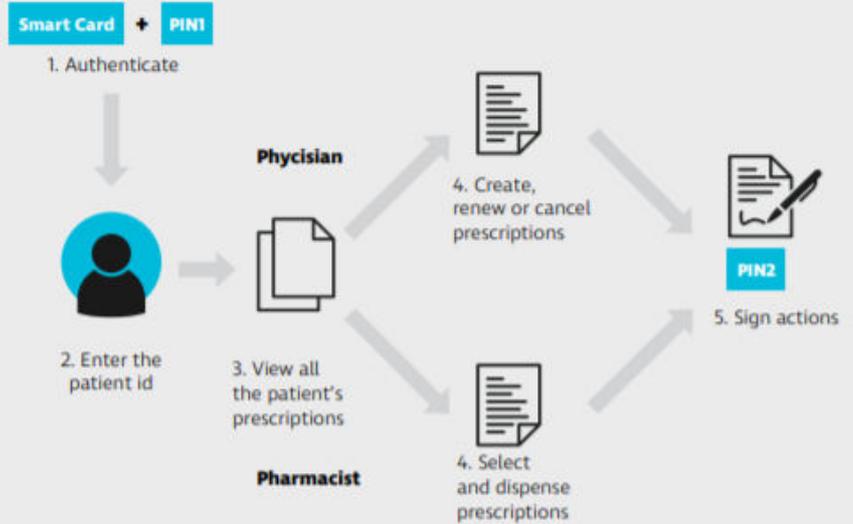


Figure 84: Illustration of the workflow of a pharmacist or a physician

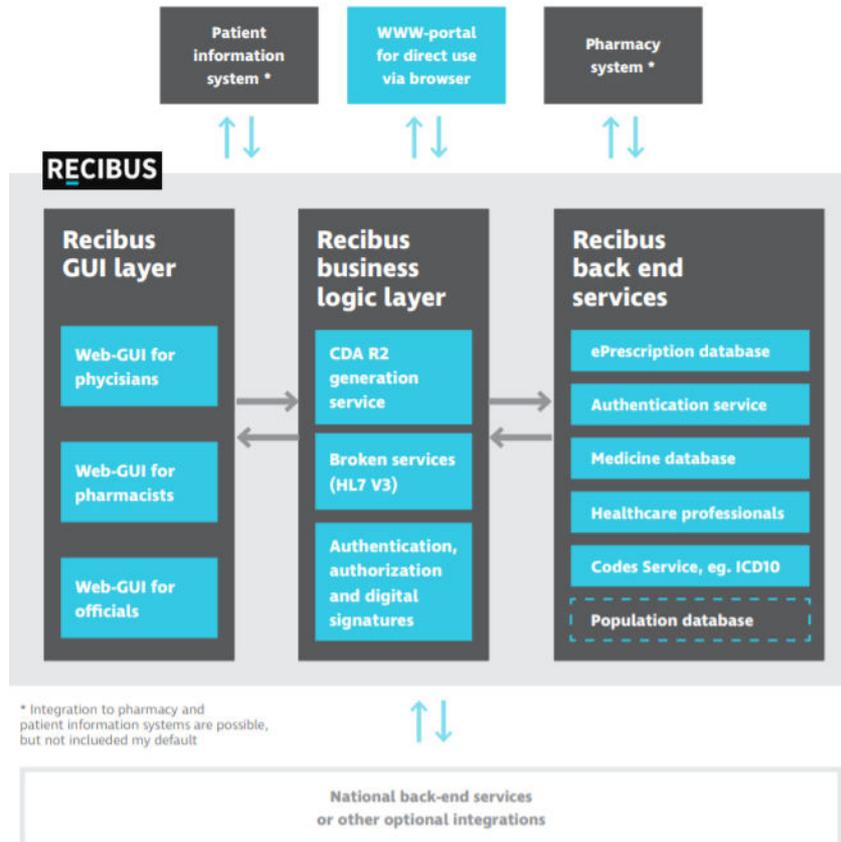


Figure 85: Illustration explaining how Recibus works¹³⁹

¹³⁹ <https://bit.ly/3bl1MI9>

Kaiku Health



Figure 86: Logo of Kaiku Health

The headquarters are situated in Helsinki and their turnover is about 4 million euros.¹⁴⁰ Kaiku Health has created a device that helps cancer patients improve their quality of life and increase their lifespan. The different symptoms are analyzed during chemotherapy to adapt the care provided.¹⁴¹

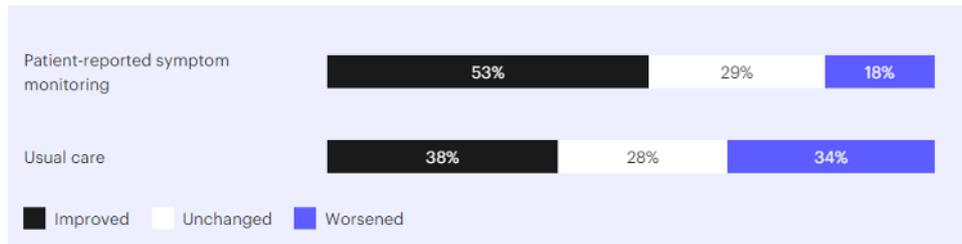


Figure 87: Illustration of the patient quality of life after six months of using Kaiku Health devices

Buddy Healthcare



Figure 88: Logo of Buddy Healthcare

The company's goal¹⁴² is to enable hospitals and rehabilitation facilities to create their own care paths. These are accessible on the patients' mobile and adapted to each of them with the advice of professionals and according to the pathology.



Figure 89: Illustration of the promises made by the company if the patient is accompanied using the application¹⁴³

This mainly concerns pre-surgery¹⁴⁴ with indications on when to stop eating, drinking, what medication to take before, during, after, etc. There are also indications on the different health paths (as rehabilitation exercises) to adopt following surgery for the post-surgery period. The patients can find different information about the operation, etc. This system allows to reduce drastically the number of phone calls and emails sent by worried patients. This lets more time for the standards of the medical structures to manage follow-ups or emergencies. Even the forms can be pre-filled on the app.

¹⁴⁰ <https://www.owler.com/company/kaikuhealth>

¹⁴¹ <https://kaikuhealth.com/for-cancer-clinics/>

¹⁴² <https://www.goodnewsfinland.com/feature/buddy-healthcare-helps-with-the-road-to-recovery/>

¹⁴³ <https://www.buddyhealthcare.com/en/>

¹⁴⁴ <https://www.buddyhealthcare.com/en/platform>

There is also a follow-up of the care path in direct time for the different doctors who accompany the patient. This makes it possible to intervene in case of slackening. Doctors also have the possibility to create reminders for a change of program etc. Their turnover is about 1 million euros.¹⁴⁵ We also find governmental organizations that call for projects to develop technological solutions to current needs. Among these we find for example Business Finland.

Business Finland

BUSINESS FINLAND

Figure 90: Logo of Business Finland

Business Finland¹⁴⁶ is a governmental organization. It was founded to raise funds and financing of projects of all types including health care. The organization has implemented several projects such as "Smart Life Finland."¹⁴⁷ It is based on personalized support and care, i.e. smart solutions based on well-being and health. The program focuses on two major points: the elements that condition well-being and health in the living environment with all the solutions that can be brought to a home with an intelligent environment that collects and analyses data but also all the solutions that can be implemented within hospitals and medical environments.

There is also another program called "Personalized health program"¹⁴⁸. It focuses mainly on the use of personal data of the different patients in order to improve their health but also their well-being. To do this, the focus is shifted on DNA and genetic diseases by creating data banks called biobanks. There has been an attempt to combine these data with the patient's environment to study their lifestyle and therefore his quality of life. All this information will allow to anticipate diseases specific to each individual and to adapt the lifestyle, environment, and care of each person to prevent any additional risks.

What unites all of these companies, is the technology that supports health. It is a flourishing market, constantly evolving and promising for the future.

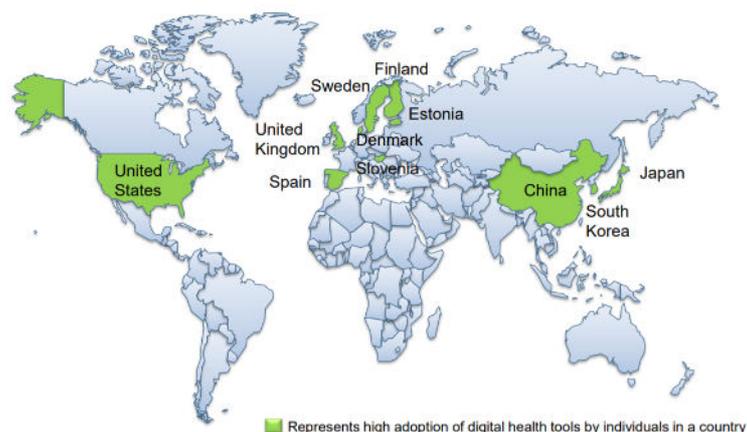


Figure 91: Illustration of the main countries that now use the e-solution in terms of health¹⁴⁹

¹⁴⁵ <https://bit.ly/3fHBznM>

¹⁴⁶ <https://www.businessfinland.fi/en/for-finnish-customers/about-us/in-brief>

¹⁴⁷ <https://www.businessfinland.fi/suomalaisille-asiakkaille/palvelut/ohjelmat/smart-life-finland>

¹⁴⁸ <https://www.businessfinland.fi/en/whats-new/news/2018/personalized-health-program-begins>

¹⁴⁹ <https://www.businessfinland.fi/49f084/globalassets/finnish-customers/news/events/2019/healthtuesday-050319-siddhart-saha.pdf>

The current problem is that there are many platforms with their own functioning which does not facilitate the work and efficiency of the caregivers. This is why projects such as Isaacus (defined later in the technological part of the PESTEL) are being considered.

7.6 5P

The 5P's allow us to elaborate the general idea of a company's marketing mix. That is to say, it is the "recipe" for a successful project.

Product	The product is a set of sensors linked together and connected to an interface in order to protect and accompany the elderly in their daily lives.
Price	<p>No prices or objectives have been decided yet, but the products listed below give us a good range of prices that already exist in the market, even if all of them aren't exactly what we are trying to do:</p> <p>BeClose: 338,75€ - Complete package of sensors, resemblance to our project : 9/10</p> <p>Qorvo: 100€ - 5 sensors and app. Resemblance to our project : 7/10</p> <p>Unali wear: 244,75€ - Watch, works with voice command, indicate the way home, alarm for medicine : 5/10</p> <p>Tempo: 143,12€ : smartwatch, monitors heart rate, general health, resemblance to our project : 5/10</p> <p>Safebed: 461,54€ - Bed attached sensor. Monitors sleep quality and breathing. falls. resemblance to our project 5/10</p> <p>If we use the grade as a coefficient to estimate what our price could be, we have this average: 258€</p>
Place	The place is the room in the building Alere. It is used to simulate an elderly person's room. The sensors will be installed there with the indications of each sensor in question.
Promotion	Here there is no sale as such. We are trying to educate nursing school students to show them the importance and usefulness of this type of system and all the benefits that can be obtained. It will be done with the help of communication panels and real-time use of sensors.
People	The people concerned by the proposed product are people over 65 years of age, i.e. the elderly, living at home.

Figure 92: Table showing the 5P of the project

7.7 PESTEL

PESTEL is an analysis composed of 5 main elements, all linked to each other. It allows a study of the macro-environment of the subject of study, i.e. here the sensors applied to Healthcare.

It helps to define the strategies to adopt, to know the different opportunities that surround us but also to understand what are the threats that surround the project.

It is an essential tool when launching a project and even more so when creating a company in a market.

The different components are¹⁵⁰ :

- the political environment which has a great influence, especially if the project wants to be taken to the international level. In this case, it is necessary to find out about each country that you want to reach.
- the economic environment, it concerns all the likely economic variations of the current environment and helps to determine if it is the right time to launch on a market. It mainly allows to take into account the factors that influence the purchasing power, its variation.
- the social environment, in our case it is very important because our project has a social asset in the first place by making more independent elderly people. It is very important to understand who will be the users of the products by studying the target of the project
- the technological environment, it is important to keep an eye on this subject not to be overtaken by the technologies of the competitors and become obsolete. The goal is to highlight what will evolve in the future and possibly what will disappear or no longer be useful (whether in terms of service or product)
- the ecological environment: this subject is becoming more and more important with the years with populations that are more and more turned towards a healthier lifestyle and a less consequent environmental impact. The goal is to understand the impact of our market on the environment and if certain activities related to ecology will impact our project (reduction of deforestation for furniture stores for example)
- the legislative environment concerns all the laws and rules to follow in the framework of our project and to be able to implement it without worry. It is necessary here to be interested in the texts of laws of the concerned countries



Figure 93: Illustration of the PESTEL graph¹⁵¹

¹⁵⁰ <https://blog.oxfordcollegeofmarketing.com/2016/06/30/pestel-analysis/>

¹⁵¹ <https://corporatefinanceinstitute.com/resources/knowledge/strategy/pestel-analysis/>

Political:

Finland's healthcare policy^{152,153} is based on a public system providing adequate treatment equally to every citizen. Therefore, anyone has access to basic care if getting ill or injured. The healthcare services are divided into primary services, delivered in municipal health centers, and more specialized services provided into hospitals. Private institutions also exist.

General healthcare, including senior, is covered by the MSAH (Ministry of Social Affairs and Health). Nevertheless, all social and health services for the elderly are managed and regulated by the different municipalities. Information and help is really easy to seek online, as the government websites are very clear about the subject.

Economic:

Health Care is the biggest cost for a senior, as the oldest we get, the more we require special treatments and care. In Finland, the maximum cost for a citizen in health care is 683€ per year, after which, the health services are free or compensated. But this doesn't include all types of services, especially as elderly people require more care, and more particular ones. Finland spent 3,036€ per person on health expenses (in 2017), which is slightly above the EU average with 2,884€.

"The European medical technology market is estimated at roughly €120 billion in 2018. The biggest medical device markets in Europe are Germany, France, the United Kingdom, Italy and Spain. The same group of countries form the top 5 IVD markets in Europe. Based upon manufacturer prices the European medical device market is estimated to make up 27% of the world market. It is the second-largest medical device market after the US (around 43%)."¹⁵⁴

Social:

As can be seen in the target study, the Finnish population is aging. As life is prolonged, people will stay longer and longer at home and the sensor system will be more and more important to implement.

On the other hand, today's elderly are a bit more technology averse than the younger generations, but people who are becoming seniors use new technologies very often and are used to them. It is therefore a generation that will be much less resistant to the implementation of connected elements in its home. The Healthcare project is therefore a promising one.

Technological:

Technology in healthcare is everywhere, new machines or techniques to monitor more and more data about patients come out every year. The IT industry represented 30% of the innovation volume from all sectors. The Medical device industry represents 7% of this volume. It means the project is in a sector full of innovations. It also means there is a lot of concurrence. But creating sensors specifically to monitor the environment and prevent risks for our seniors, is a sector with not as much activity as one could find in a bigger machine, like x-ray, or MRI for example.

¹⁵² <https://stm.fi/en/older-people-services>

¹⁵³ <https://www.eu-healthcare.fi/healthcare-in-finland/healthcare-system-in-finland/>

¹⁵⁴ <https://www.medtecheurope.org/datahub/market/>

One of the biggest technological developments¹⁵⁵ is the implementation of the Isaacus¹⁵⁶ project led by Sitra^{157,158}, the Finnish government but also many medical structures such as hospitals etc. (like the Hospital District of Helsinki or Hospital District of Southwest Finland). The aim is to collect personal data for social and medical purposes in order to improve the quality of services within home service for the elderly, family social work or youth work.

This project will be a data-secure environment managed and protected by THL, Statistics Finland, Biomolecular Resources Research, Infrastructure Institute for Molecular Medicine Finland and Statistics Finland to help medical facilities understand and analyze the data they collect.

The project is in development, it started in 2016 with the project proposal to the government to get rights to use private data. Since then, a law has been passed to allow access to this data to relevant entities.

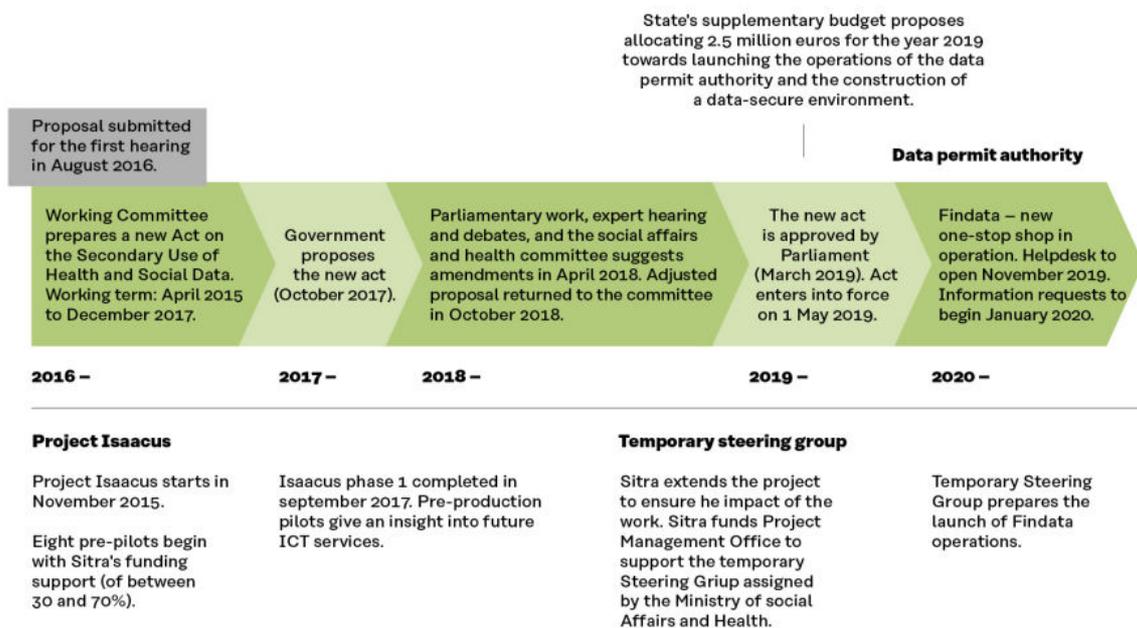


Figure 94: Illustration of the evolution of the project¹⁵⁹

Nevertheless, access to this data remains sensitive for many people. This might scare many citizens of many countries but not the Finns. Indeed, the government has an extremely transparent policy which makes the notion of "trust"^{160,161} very much embedded in society today. People trust their government as no information is hidden from the people.

¹⁵⁵ <https://www.businessinsider.com/most-innovative-industries-2015-5>

¹⁵⁶ <https://www.sitra.fi/en/projects/isaacus-pre-production-projects/#what-is-it-about>

¹⁵⁷ <https://www.sitra.fi/en/publications/a-finnish-model-for-the-secure-and-effective-use-of-data/#abstract>

¹⁵⁸ https://youtu.be/yP_o493Qnnw

¹⁵⁹ <https://www.sitra.fi/en/publications/a-finnish-model-for-the-secure-and-effective-use-of-data/#abstract>

¹⁶⁰ <https://bit.ly/3hJmwwv>

¹⁶¹ UN Sustainable Development Solutions Network : World Happiness Report of 2020

It is therefore thanks to this trust that the government was able to pass the law for access to this type of data. In order to protect its citizens, certain restrictions are applied to the access of this data. The actors of the project are thinking about setting up a data access permit that will vary according to the actor. Depending on whether he is a researcher, whether he works in data monitoring or whether he is in charge of data maintenance he will not have access to the same information. For some the data is anonymous, for others more detailed etc.



Figure 95: Illustration the using of data¹⁶²

Today the project is mainly created for research but also to know the costs around health, to know if the services made available are well exploited and fairly exploited in Finland. To make the project unbiased and to make sure that it is conducted for health and not for profit, it will only be allowed to non-profit companies.

It is indicated in Sitra's evolutionary pathways that today it is more complicated to take into account the parameters of a person's environment such as air quality or temperature to determine the impact on a person's quality of life. Nevertheless, doctors agree on the point that these elements really impact the health of the person and that it is necessary to include them in the data that will be exploited. And this point is in line with the "Healthcare Sensor" project which implies the use of sensors applied to a person's living space.

¹⁶²<https://www.sitra.fi/en/publications/a-finnish-model-for-the-secure-and-effective-use-of-data/#abstract>

Environmental:

Sensors are electronic compounds, and electronic compounds mean pollutants. In order to restore the ecological balance with the planting of trees or citizen actions. Nevertheless, it is necessary to know the construction of the final device to evaluate the environmental impact.

Legal:

The legal environment around sensors and even more around IoT is very important, especially if this system is set up in a home. The main rule is about “The Data Act”¹⁶³. You can find the rules of using data in and how you are able to use them according to a European agreement. Nevertheless, things have changed a lot in recent years in terms of protection, storage and sharing of personal data thanks to a recently passed law. The law is more commonly known as “Secondary use of health and social data” according to the General Data Protection Regulation. It comes to implement and complete a European law: The EU’s General Data Protection Regulation (adopted in 2016 and established in 2018)¹⁶⁴.

It will be about knowledge management to help the government as well as the medical authorities to be able to better accompany the patients and to understand which are the most adapted care and life cards for the various categories of citizens (young children, workers, old people...). With a clear and defined law, it is much easier to use data while respecting the privacy of individuals.

As described in the paragraph on the technological environment, to access this data you will need a permit; and depending on the person, the permit will not give access to the same information. The sensitivity of the shared information will be assessed by a neutral entity whose main activity will be to monitor the evolution of the data, the attribution of the data and to study the way the data is exploited. The goal is to ensure the security of everyone's data and guarantee privacy. All of those elements are defined in the Act on the Secondary Use of Health and Social Data.¹⁶⁵

This is all still in the project stage, launched in 2016. The law is established but there are still many things to be put in place such as the information HUB related to people's data, the entity that will manage the issuance of permits for data access, the referencing of possible actors, the way data can be processed for research, the data considered too sensitive and that should be anonymous, those that can remain public etc.

About IoT and how to protect its network it is possible to find several tips in the document ETSI TS 103 645 V1.1.1 written by Etsi. It provides the “first globally applicable standard for consumer IoT security” which is linked to the norm EN 303 645 also written by Etsi.^{166,167} Few directives are written on different subjects about the use of sensors in the environment to best adapt them and know when

¹⁶³ <https://www.finlex.fi/en/laki/kaannokset/2018/en20181050.pdf>

¹⁶⁴ <https://eur-lex.europa.eu/legal-content/FI/TXT/PDF/?uri=CELEX:32016R0679&from=EN>

¹⁶⁵ <https://bit.ly/3bJh6xF>

¹⁶⁶ <https://bit.ly/3vcTwkB>

¹⁶⁷ https://www.etsi.org/deliver/etsi_ts/103600_103699/103645/01.01.01_60/ts_103645v010101p.pdf

to highlight a danger. For example, there is the “The Clean Air For Europe Directive” (2008/50/EC) which is about the air quality outdoor and indoor (IAQ). To be more efficient on that subject it’s possible to use the ISO/TC 146 Air Quality Technical Committee which is a standardization for the air quality measurements methods.¹⁶⁸ If the project has to be on watching the good hydration of someone it’s possible to use the European Drinking Water Directive (98/83/EC)¹⁶⁹ to know the amount of water a person should drink etc.

Response to the problem and the objectives of the study

As a reminder, the objectives of the study were as follows:

- Understand the project environment
- Define the target audience for the project
- Define the appropriate market
- Identify the industries that offer this type of service
- Define the strengths and weaknesses of the project

Analysing these study objectives will help answer the following question:

What services can be put in place to facilitate the life of the elderly and the caregivers with the help of sensors?

Many things came out of this research. Firstly, it is a developing market with projects led by the country's hospitals and with the help of the government. There is a real awareness of the need to set up these types of devices. The needs and expectations of the targets have been clearly defined. On one hand, for the elderly, it could be a discreet accompaniment that could allow them to continue living independently and being reassured by a non-intrusive monitoring of their health. Some people are still too afraid of technology and the idea of being permanently "monitored" but understand the necessity and usefulness of this type of system that can reassure them and their families. On the other hand, there is a whole healthcare sector. These are people who are more and more willing to accompany their patients psychologically and in a more social way. They see great opportunities in the installation of sensors in the homes of people, especially if they are alone, to prevent falls (often fatal) or forgetfulness related to Alzheimer's, dementia, etc. This would allow a daily monitoring in parallel to their care to detect for example a significant weight loss in a short time which can be a sign of depression.

As far as the targets of the survey are concerned, everything seems to suggest that today's society is inclined to this type of project and even recommends it. The strengths of the project are therefore the novelty brought and the strongly reinforced support. The weaknesses are more of a monetary nature with the maintenance that this type of project can generate or the intrusiveness of these devices.

The appropriate market is non-existent currently - that is, there is no preferred sale since it is not the type of purchase that a person living alone at home would make. If it is a device that is sold, it will have to be recommended by the nursing staff to the person(s) concerned as well as to the families, the benefits that can be obtained from this type of device should be shown and explained. It is therefore a time-consuming method but based on the trust that is given to the caretakers, and

¹⁶⁸<https://bit.ly/2Sh3hjt>

¹⁶⁹https://www.researchgate.net/publication/301166543_Regulations_and_Standards_Considerations_for_Sensor_Technologies

therefore a well-thought act: if someone chooses to install sensors it will not be a compulsive purchase, once installed they will remain installed and prove their efficiency.

There is no equivalent market, but there are indirect competitors. They offer one element of the project, such as the implementation of a security network or health parameters controllers, but none of them brings everything together. It is a flourishing market that generates significant turnover both in the world and in Finland. In Finland the test panel is smaller than in other countries due to the number of inhabitants but the very strong trust of the Finnish people in their government gives much more freedom on testing and developing new solutions.

7.8 Corporate Identity

Once the needs are understood, it is then possible to develop the whole identity of the brand. All this serves as a "showcase" for the project. It gives confidence and credibility to the project. With the help of all the elements such as the logo, the name or the slogan, it is necessary that an external person can immediately understand the subject. This allows to catch the attention of the interested and concerned people or to arouse the curiosity of the others.

7.8.1 Brand name

How to define a brand?¹⁷⁰

The main points to think about when creating a brand are the following:

- clearly know the target that we want to reach with our brand (needs, expectations, fears, evolutionary perspectives...)
- find out and define the brand's domain
- define the name of the brand
- check that the name in question does not exist and that it does not belong to another company
- define a logo
- define a slogan
- check that the name in question does not exist and that it does not belong to another company

Developing our identity began with a name.

To define the name several methods can be used:

- use keywords related to the environment of our service
- choose the name of the brand according to the market we want to reach (accessible to the whole population, luxury market etc.)
- be inspired by foreign brands
- draw inspiration from the major brands within the country
- use English to capture a more general audience in case of a more international development of the project
- it's better if it can use

To find it we exchanged on the elements that we wanted to bring out with our name.

The main ideas revolved around the notion of care, the fact of being connected.

We then suggested the following different names:

- Stealth Health

¹⁷⁰<https://www.conseilsmarketing.com/promotion-des-ventes/comment-choisir-un-bon-nom-de-marque-dentreprise-ou-de-site-internet/>

- Sensing Support
- Smart Cover
- HeathConnect
- Ed-Care
- Invisible Healthcare
- Elevated Care
- iCare
- E-Ilderly
- HealthCo.net
- Safety Senior
- SenHealth
- SenConnect
- Ecarus
- StealthHealth
- WeCare
- Innovation Senior
- Valkar-e
- ValCary
- Valkarie
- Valkyrie
- We-carus
- MyCare
- E-mpower
- E-mproving
- **Care&Connect**
- LeadingSenior
- CareConnect

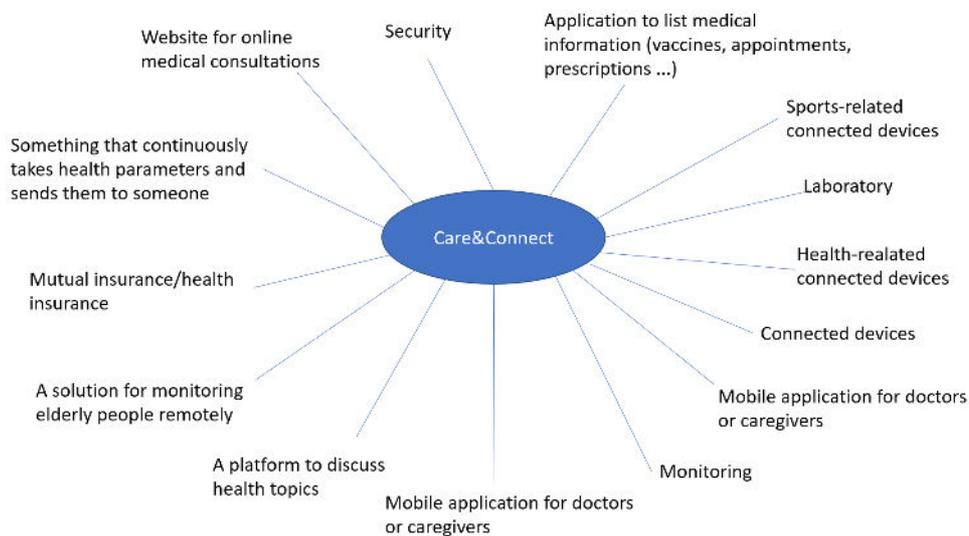


Figure 96: Mapping of people's thoughts and ideas after hearing the name "Care & Connect"

The main idea was about monitoring and taking care of people, which is perfect because it is the main scope of the project.

7.8.2 Logo

The logo of a brand is what people are going to remember. For example, if you think about one of the biggest brands in the World as Coca-Cola or Apple you will be able to associate the logo with the brand directly. It is one of the biggest parts of communication.

To create a logo, an identity, it is always necessary to identify the message that one seeks to return before the illustration that one wishes to propose. That's why many brands have updated their logo over the years. Indeed, consumer expectations and trends evolve, and if a brand wants to stay in the trends, it must absolutely keep up with the evolutions and be ready to update its logo.

Nevertheless, it is important not to lose the initial identity of the logo. It should not be changed at all, especially if the brand is not well known, it could disturb and lose the "loyal customers".¹⁷¹

To create the most suitable logo several questions can be asked such as¹⁷²:

- the target: age? Female target? Male target?
- positioning: are we looking to reach a luxury market? Middle of the range? Accessible to all?
- values: positioning is not the only element that defines the type of market, but there are also the values that we wish to attribute to the project. Is it a product with wellness values such as Evian? Is it a product that is supposed to bring people together like Fanta?
- quality: is it a brand that sells highly technological products? Is it a service?
- cultural: is it trying to reach certain populations? Europe? India? America? Are there codes to follow for these countries and what are they?
- the tone: are we trying to sell a serious product? A product that allows you to have fun? A service that helps you feel good?
- the colours: are there any colours associated with the brand's domain?
- the shapes: are there any shapes that correspond to the brand's domain?

Also, what are the tools we have at our disposal to create our logo? Are we going to use an agency? Do we want to create it using tools that are accessible to the greatest number of people? Does the logo need to be worked on? Do you want to combine writing and illustration, or do you only want one of the two?

Within the framework of the Healthcare Sensors project, we have a well-defined target profile: a **mixed Seniors European population** based on a **mid-range market** to offer quality services without preventing a large part of the population from having access to them by basing ourselves on an overly luxurious market.

The values of the project are based on **care** and **support** but also **monitoring**. The proposed product is a technology focused on the care and health of the person, it is therefore considered as "**highly technological**" and has to be **serious**.

About the colours (**in a European point of view**):

¹⁷¹ Marketing course from IUT CHAMBERY UNIVERSITE SAVOIE MONT BLANC (Provided by Karinne LIERES ANDRE)

¹⁷² <https://www.columnfivemedia.com/how-to-choose-a-brand-name>

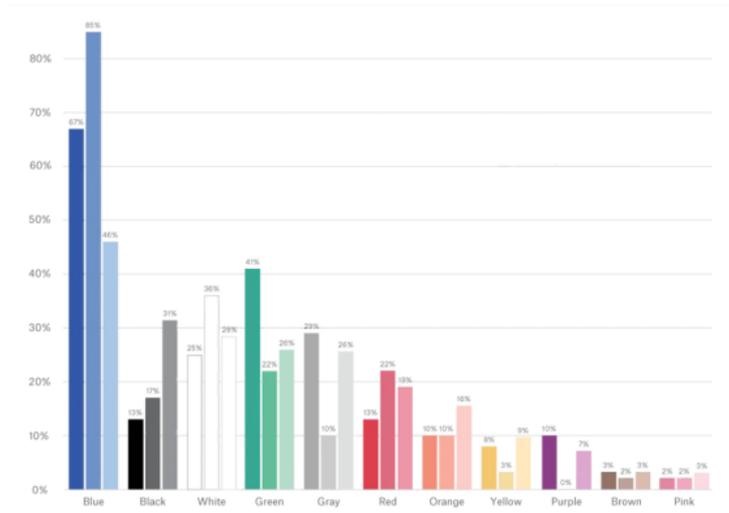


Figure 97: Graph of the different colours used for health¹⁷³

In this graphic it is possible to see that the main colours linked to health are blue, green and white.

Colour	Blue	Green	White
Meaning	<p>Blue is a primary colour linked to dreaming as well as to wisdom and serenity. It is the symbol of truth and is a refreshing and revitalizing colour. The darker the blue, the more it has the function of highlighting as the colour blue is related to royalty. On the other hand, the more pastel it is, the more it is associated with serenity, well-being and escape. Moreover, blue is the most beloved of all colours. It is not a risky colour to integrate in your logos.</p>	<p>Green is a secondary colour composed of blue and yellow. Green is above all the colour of nature and connected to the Earth. Green will have a refreshing effect but also invigorating, it will give life to the logo and its highlights. Green is also associated with hope and luck as with the four-leaf clover. Green therefore brings a notion of vitality, energy and hope.</p>	<p>White is the combination of all existing colours. White is the symbol of purity but also lack of accomplishment, or emptiness. White is certainly associated with the medical field but with the help of packaging to communicate in the clearest way possible. A logo made of white would lack visibility. But it would also introduce a balance. White can therefore be used in a logo but always accompanied by strong colours and it must be used sparingly.</p>
Example of brand's logo			

¹⁷³ <https://99designs.ca/logo-design/psychology-of-color/healthcare>

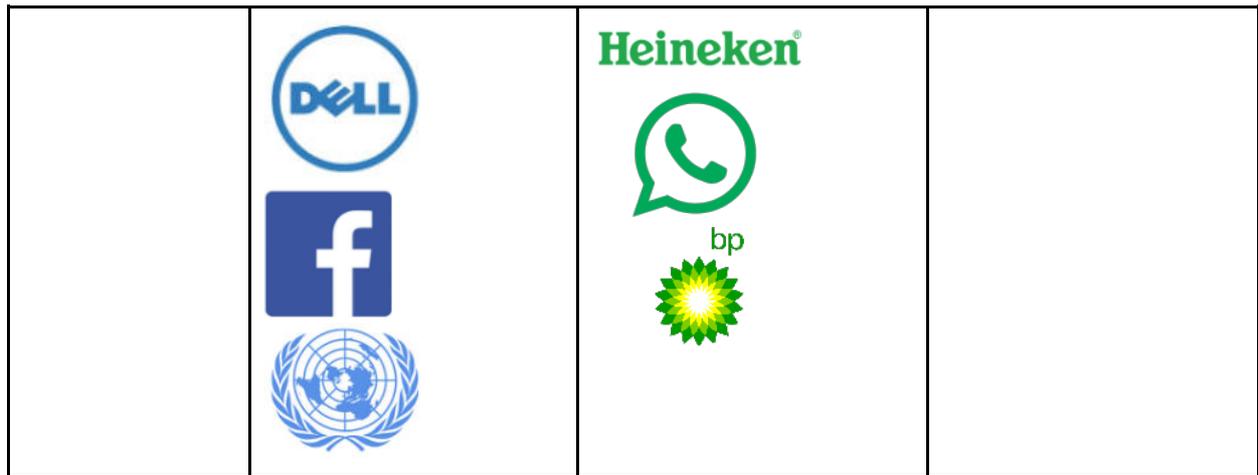


Figure 98: Meanings of the main colours¹⁷⁴

In Finland, when we talk about the colours of health, we also find these three main ones. For example, when looking at the logos of different areas of health such as hospitals, nursing homes and health institutions we can find this type of logo:



Figure 99: Pell-mell of Finnish logo about health

On the other hand, if we try to list the colours related to the elderly as well in the care as in the various services which are set up for them (ex: old people's homes) we have colours a little more varied



Figure 100: Pell-mell of Finnish logo about seniors

When it comes to retirement home or communication aimed at seniors we can identify green, blue, yellow¹⁷⁵, brown¹⁷⁶, and orange colours.

¹⁷⁴ <https://www.code-couleur.com/>

¹⁷⁵ <https://www.arretsurimages.net/articles/de-la-couleur-des-logos>

¹⁷⁶ <https://www.logomaker.com/blog/2017/11/29/when-should-you-use-a-brown-logo-for-your-business/>

While one focuses on companies that offer care to the elderly, a lot of blue and green can be found but also red when it comes to health equipment.

Colour	Yellow 	Brown 	Orange 	Red 
Meanings	<p>The yellow is very bright. It echoes dynamism, warmth, summer. It is a colour that is associated with celebration and joy. A logo with yellow is a logo that will attract attention. Nevertheless, the brighter the colour, the more it is synonymous with action, speed. The more the colour tends towards pastels the more it is synonymous with softness. Yellow is also the colour of power referring to gold, to power. The yellow can also be linked to learning.</p>	<p>The first association of brown is with wood, something natural and solid. It is a neutral and reassuring colour. It echoes both flora and fauna with the coat of many animals. Brown is often used as a complementary colour in logos and not as the main colour. It brings content to the logo and supports the strong colour of the logo, the main message. If used alone it refers to escape and travel or the field of chocolate or coffee.</p>	<p>Orange is a colour that brings energy: just like the fruit it brings energy and good mood. It is the major symbol of creativity, open-mindedness and optimism. It is also the stimulation of communication and the stimulation of the senses. Orange can be associated with the colour of the flame, always in motion. When orange is bright it can be associated with elements that are not of very good qualities. The garish colour seeks to attract attention to sell an object that the consumer does not need. So orange is often associated with junk food, soda, candy, etc. It is also associated with the party, the excitement with the idea of movement and stimulation of the</p>	<p>Red is a very strong colour, it marks the eye and we must be very careful when trying to use it. It is above all the colour of passion, of love but also of terror and war. Therefore, red is considered one of the strongest colours to use but also one of the most difficult. Red appeals to temptation but also to prohibition at the same time. It is an energetic colour and is described as "penetrating": it marks and remains in the lead. Red is also the colour of greed with red fruits such as strawberries or raspberries. Red is also a warm colour that evokes well-being with the idea of flames that come to warm. It is synonymous with life and vital</p>

			<p>senses.</p> <p>If the orange is more pastel, softer the logo takes a more down to earth notion and addresses the notion of origins. We can find many travel agency logos using associations with orange. It has an antidepressant function.</p>	<p>care. It can also be associated with speed and performance.</p>
Brand's logo				

Figure 101: Meanings of colours associated to elderly¹⁷⁷

If we have a look on the biggest Healthcare Companies and more especially on their logo it's possible to notice that they all use the same colours.

¹⁷⁷ <https://www.color-institute.com>



Figure 102: The 10 biggest Healthcare companies in the world¹⁷⁸

There is a lot of dark blue, red and green. These colours are therefore the conductive colours. The goal is not to copy but to be inspired to understand the colour codes of the market but especially of the dominant companies.

About the shapes (in a European point of view):

The logos representing the health care fields (and in particular the equipment) are mainly illustrated only with the name of the company. This gives a more serious and identifiable look for professionals using the products. They have directly the name of the people who offer the service or the product and it is sometimes easier to inquire afterwards.

As for the devices made for the elderly we find simple logos with the name of the company/structure accompanied by an illustration.

The forms used are mainly silhouettes of intertwined people representing the family, the accompaniment. There are also many round shapes that illustrate caring. It is the symbol of perfection but also of the cycle of life. We can also find silhouettes of hands that surround or support the person(s).

Finally, it is also possible to see a silhouette of an elderly person accompanied by a younger person who accompanies and supports them.

The key words of the project being care, help, accompaniment and monitoring it is also important to know what forms are associated.

Word	Shapes
Care	Cross Caduceus with the snake Part of body as tooth, foot, eye according to the care given Cardiogram Heart Stethoscope Bandage
Accompaniment	Hands Bird(s) shape

¹⁷⁸<https://www.investopedia.com/articles/markets/030916/worlds-top-10-health-care-companies-unh-mdt.asp>

	People supporting/helping one other Arrow
Monitoring	Eye(s) TV Camera Networks Link Dog shape Head shape
Help	Hand supporting something (a person, a house, an animal ... depends on the company/association) Hands Head Headset

Figure 103: Table of the different shapes used as logo according to the key words of the project

7.8.2.1 Designing part

In the marketing analysis it was explained what kind of shapes and colours there should be used and from there on out we started the search on existing logos. Trying to see what the market is doing and how we can implement existing ideas into better ones.

The growing trend at the moment is minimalist design which initially emerged during the 1950s and 60s as reaction to an undeniably noisy, technologically advancing culture. The sudden simplicity, clean lines, and white breathing room started to show up increasingly more in visual cart, engineering and graphic design.

The gritty, collage driven styles of the 90's were replaced by the explosion of bright colours of the mid 2000's, and by the 2010's, minimalism was more than prepared for a rematch. Just now are we seeing its ability to grab the attention in this constantly evolving and scrolling culture of web-based media or mobile experience. From clean and spacious websites to Instagram taking care of elegant portrait level photography, brands across the globe are completely accepting the minimalist design trend.

Examples of this kind of evolution are:

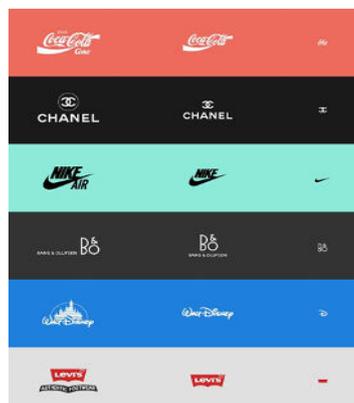


Figure 104: Evolution of logo from different popular companies

How does this translate towards a logo?

Logo design is one of branches where minimalism is generally mostly used. This due to the fact that the amount of space you get for a logo is so small that it has to stand out. Everybody needs a logo that sticks out, that creates an instant reaction, and leaves a long-lasting impression of your companies' qualities and norms. The less jammed packed this little space is, the more rapidly and productively that message can be communicated.

There isn't one approach to do a moderate logo plan. Famous styles for logos incorporate geometric shapes which makes it easy for the eye to comprehend, flat line design which gives you freedom to visually explain the brand and typography design which clearly communicates the brand name. While some of these designs are adorable and memorable, the really astounding logos create their logo out of a combination of shapes and typography (example down below).



Figure 105: Example of a logo which uses typography

While minimalism seems "simple" to a non-graphic designer, A trained eye knows how much time and creativity it takes to create a perfect, cleaned up design. Minimalism is feeling his mark on the world and it's believed that it will stay for a while, especially if it can say so much in so little. Whenever a minimalistic design is done well, clients and shoppers will not give it a second thought — despite the fact that, unexpectedly, the designer has invested a huge amount of time and energy into causing it to appear to be easy!

More examples:



Figure 106: Examples of minimalistic design

In the search for this project’s logo, we decided to combine multiple shapes together to portray the room, the name or the general idea. These shapes have been defined in the marketing analysis before to see what kind of shapes the consumer identifies as health care and which not.

For the portrayal of the room itself I thought of showing a “personal house” this with the hidden meaning that not every house is the same and that every house that is fitted with the sensors can be personalized to the needs of the owner/user.

This meant finding the right objects to translate the word “personalized”, the ideas and the things found on the internet were a person in the middle, fingerprint and a gear (shown down below). The room was an easy gander (but nonetheless down below are some internet searches).



Figure 107: Sketches (1)



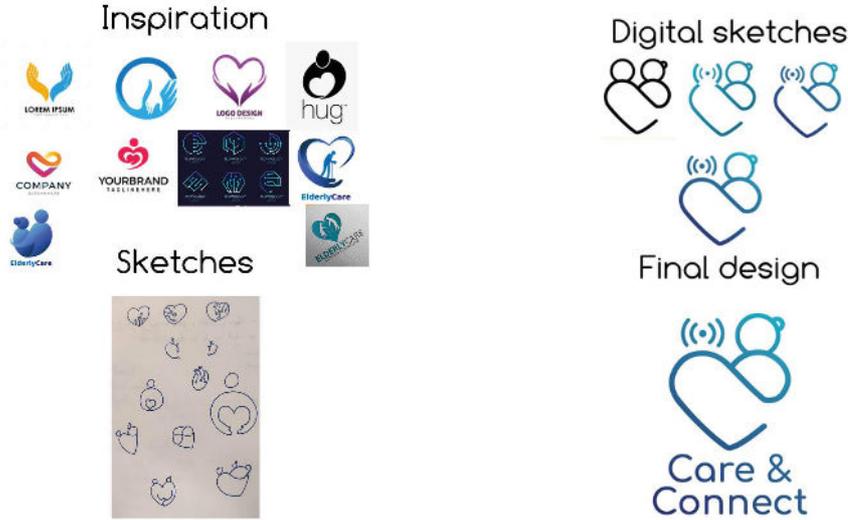
Final design



Figure 108: Sketches (2)

For the portrayal of the name itself, which is Care & Connect we had to look at what the words mean and what they want to envision. Care means to love someone and to take care of this person which can be portrayed as a hand or heart, while connect can mean the connection via the internet or to literally connect with someone via hug or talk.

Those were the literal meanings of the words but what the name wants to represent is the care and connection for the elderly so the elderly should be included in this logo too. Which brings us to the possible use of: hands, heart, hug, technology and the elderly (existing logo's down below). The last thought process was to try to get the general idea out in which it tells the story on it's own.



_Figure 110: Sketches (3)

Figure 109: Sketches (4)

This is a harder study since this normally takes up to 3 months to come up with a good idea and to find the right composition for this idea.

But nonetheless we defined the shapes which would be used, this time to convey the help of the sensors in the medical field: medical cross, hands, technology (sensors) (existing logo's down below and above).

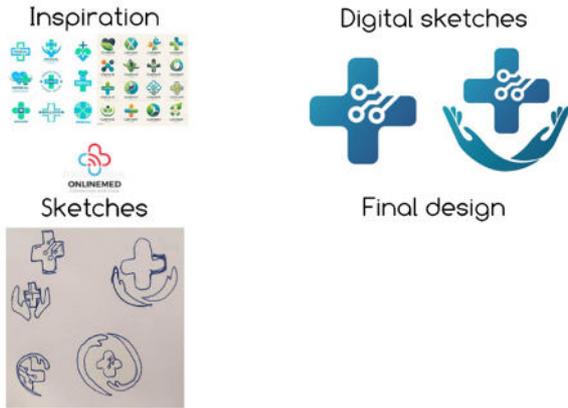


Figure 111: Sketches (5)

Typography

What is Typography?

Typography is the skill of arranging letters and characters – also called type - into a composition of forms so that your design or web design sends a certain message towards your visitor or client.

In this it is important to choose the right font to portray the right idea, not every font is useful in every situation.



Figure 112: Why fonts matter

Examples of why fonts matter

What's So Important About Typography?

Even the smallest changes in typography make a big impact. Even the smallest changes to the spacing between letters and thickness of these letters affect how easy it is to read your text or smaller screens such as a phone. For instance, Helvetica Neue was utilized by Apple preceding changing to an in-house font. This in-house font gave Apple the ability to make their texts easier to read by utilizing more space between the letters so the reader could breathe more, this was a major change for the iPad and iPhones.

At some point in your design, you should take your audience in consideration, senior people might need a bigger font that has more spacing between letters, while a younger audience might appreciate smaller fonts with unique curves.

Fonts or typefaces?

In spite of the fact that fonts and typeface are utilized similarly, these words really mean two unique things. Typeface alludes explicitly to what you find in an inventive piece, while font is the actual collection of letters and characters.



Figure 113: Difference between Font & typeface

Things to consider while using Typography.

In papers such as these it is advised to have enough white space in between alpha and numeric characters so that these characters are not misunderstood. For example, when superscript or subscript letters or numbers are used then the font or typeface should allow for enough leading, kerning or tracking so that these characters don't melt together.

Leading: The distance between each line of text.

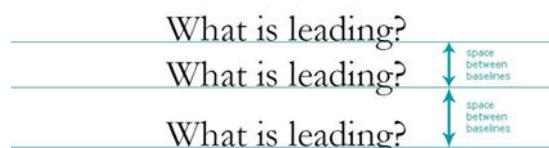


Figure 114: Leading explained

Kerning: the adjustment of space between 2 individual letters or characters.



Figure 115: Kerning explained

Tracking: adjusting the space uniformly in between letters or characters.

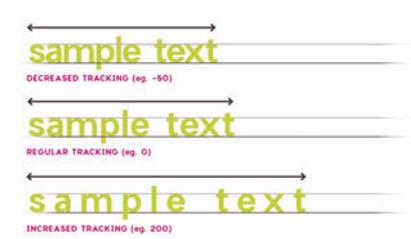


Figure 116: Tracking explained

With this information in the back of our head I started the search on which font or typeface would be suitable for this project. With an abundance of previous research for the right font in medical projects it is clear that not just one font can do the job.

Out of the previous research it can be deduced that there are 10 fonts which do the job. These being Verdana, Lora, Source Sans Pro, Proxima Nova, Times New Roman, Rockwell, Avenir, Comfortaa, Quicksand and News Cycle

In which I made a selection of 3 Fonts: Comfortaa, Quicksand & News Cycle.



Figure 117: Examples of the fonts Comfortaa, Quicksand and News Cycle

Colours

The main colour is already decided in the market analysis, which is blue, but blue has a wide spectrum of colours underneath this one word. To tackle this problem, it is best to create multiple colour palettes and see what kind of feeling these colours create.

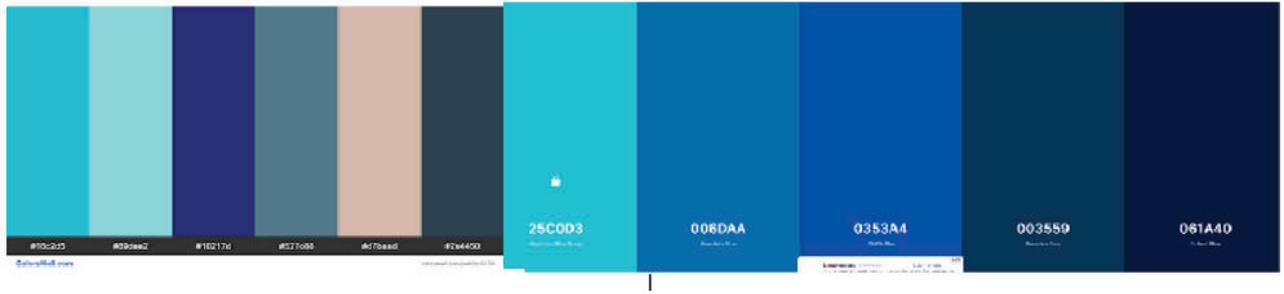


Figure 118: Colour palettes

From there on out it's trial and error in which colour combination fits the project best. Not to forget that personal taste affects the end decision.

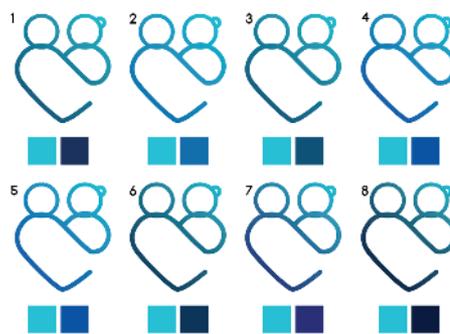


Figure 119:Color iteration of gradient

Out of these it was the end decision between number 3 and 7, in which 7 was the end the winning choice.

Culmination of Logo, Typography and colour



Figure 120: Enddesign

7.8.3 Slogan

The slogan^{179,180,181} is part of the brand identity and is the biggest challenge of the brand. It is a catchphrase. If the slogan is well thought out, it is the consumers who will advertise the company instead of the company. Indeed, well thought slogans such as "Just do it" from Nike or "Yes we can" from Obama during his presidential campaign are phrases that stay in mind. If someone pronounces them, we can directly associate them with the person or the company in question. If we pronounce a sentence that is close to it, we can also make the link with a famous slogan like "Have a break, have a KitKat" from KitKat which comes very easily in mind when we talk about taking a break. A well-executed slogan gives a lot of power to the company.

So, it's interesting to ask how a good slogan^{182,183} is thought out and designed. First of all a slogan has to be very simple, understandable by everybody and **short**. The pronunciation has to be easy to be repeated by people. The main goal is to write down all of the most important concepts around the product or service sold and try to create something with.

The questions which have to be answered before doing anything are the same as the ones for the logo. That is to say:

- the target: age ? female target ? male target ?
- positioning: are we looking to reach a luxury market? Middle of the range? Accessible to all?
- values: positioning is not the only element that defines the type of market, but there are also the values that we wish to attribute to the project. Is it a product with wellness values such as Evian? Is it a product that is supposed to bring people together like Fanta?
- quality: is it a brand that sells highly technological products? Is it a service?
- cultural: is it trying to reach certain populations? Europe? India? America? Are there codes to follow for these countries and what are they?
- the tone: are we trying to sell a serious product? A product that allows you to have fun? A service that helps you feel good?

The tone will help to know the kind of "catch phrase" to use:

- Is it necessary to use deep words with a hidden meaning ?
- Should we use humor?

The values will help to understand the direction in which to turn the slogan:

- Is it necessary to set up a challenge?
- Is it necessary to appeal to greediness?
- Are we dealing with a sensitive subject on which precautions must be taken (religions, diseases etc.)?

One of the important elements to try to add to your slogan is to bring rhythm. Like a song, it needs to stick in your head. Adding rhymes to it can further support the concepts and get the slogan stuck in people's heads.

The slogan has to match with the logo. They complete each other. Just like logos, they must be rethought with time to always correspond to the current society.

¹⁷⁹ <https://examples.yourdictionary.com/catchy-slogan-examples.html>

¹⁸⁰ "Got slogan? Guidelines for creating effective slogans" by Chiranjeev Kohli, Lance Leuthesser, Rajneesh Suri

¹⁸¹ <https://www.logaster.com/blog/slogan-generators>

¹⁸² <https://www.verticalresponse.com/blog/7-tips-to-creating-a-memorable-slogan/>

¹⁸³ <https://www.activecampaign.com/blog/company-slogans>

Another point to captivate the audience even more is to find the point on which it is possible to differentiate from others and put it forward. This method is often used in the context of technological innovation or by artists to differentiate themselves from the many competitors.

The ones we were able to find are the following:

- A sense for healthcare
- Choose freedom
- Committed to sense your needs
- Sensors to protect
- Get your health checked
- C&C Live healthier, live happier
- C&C Without regret
- C&C Living Innovation
- Sensorly yours
- Make seniors great again
- C&C good products and good prices
- **C&C, Your digital helper**
- Let the visible make your life better
- Distance is not a problem
- Live your future perfect
- C&C we treat you with respect
- C&C it's our project

We chose the “C&C, your digital helper” according to our target but especially to the product we propose. It is a technological product for elderly people to improve their daily life but especially to avoid and prevent the usual risks. To know if it was well-chosen, a panel of people was asked what would be the most appropriate logo and the name for the project. The slogan was selected at 70%. It is therefore clear that this slogan is appropriate for the chosen project. Now that the slogan has been validated for a defined name, it is interesting to know what the slogan can mean for people who are not involved in the project. This allows us to put ourselves in a real situation and see if the slogan is strong enough and correctly targeted. Therefore, other people were asked about this and their feedback is as follows:

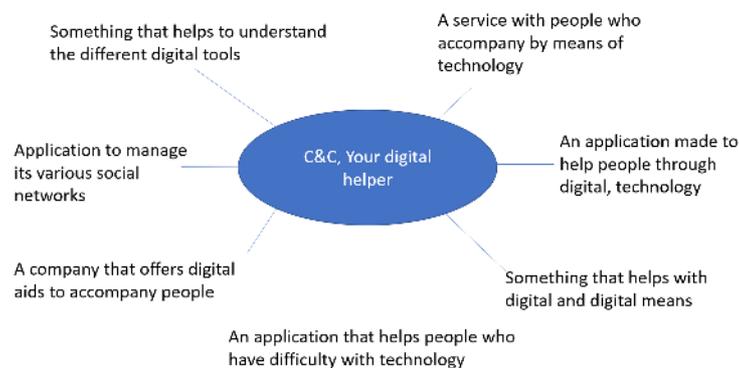


Figure 121: Mapping of people’s thoughts and ideas after hearing the slogan “C&C, Your digital helper”

The main ideas were about the digital, the technology and the idea of helping people which are perfect because they are the main scope of the project and the idea we would like to transmit thanks to the slogan. Moreover, we asked if it is a slogan they would remember easily and the answer is yes for 100% of those interviewed.

We defined the name "Care & Connect" to link care and connected sensors.

Within the framework of the Healthcare Sensors project, we have a well-defined target profile: a mixed Seniors European population based on a mid-range market to offer quality services without preventing a large part of the population from having access to them by basing ourselves on an overly luxurious market.

We created a logo with blue colours recalling the care and the medical field by choosing forms which imply the accompaniment and the old people.

Then, the slogan "Your Digital Helper" was chosen always for the idea of accompaniment and help in relation to the digital domain that will come to help the person within his home.

8. Practicalities

To carry out the project, it was important to think about several points such as how to hide the sensors so that they are not too intrusive in someone's daily life or the whole coding part of the chosen sensors.

8.1 Cases

It is unthinkable to leave the sensors as they are, without proper protection. Using a CAD (Computer-aided design) software called CATIA, cases for each sensor were designed, according to each sensor's dimensions and restrictions. Then, using the resources from Technobothnia, the cases were 3D printed.

The boxes need to be discreet and rather small, but there is no restriction on their weight. PLA was a good material of choice as there are a lot of colours available that could fit into any background (in this case, for the healthcare room in Alere, white was enough, but we could imagine different wall colours), this material is also light and resistant to small shocks, which should be enough for their use, since they will not move once they are installed.

8.1.1 Motion sensor case

The motion sensor's case was the first to be designed. The motion sensor and the ESP32 needed to fit in it, as well as the wires linking the two components. After having taken the right measurements, this is what the first design looked like:

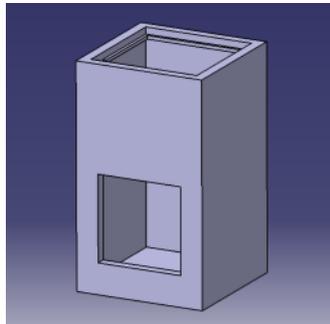


Figure 122: First design of the motion sensor case

The motion sensor should fit in the hole facing us. The components go into the case from the top, and there is just enough space, so everything fits together, and nothing rolls around in the box. The problem with this design was the power supply. Indeed, the ESP32 needs a power supply with a micro-USB wire linking the component to a socket. But on this design, there is no hole for the wire to connect to the ESP32. The way this was designed, the socket on the component was either facing toward the top or the bottom which aesthetically was neither very pleasing nor practical.

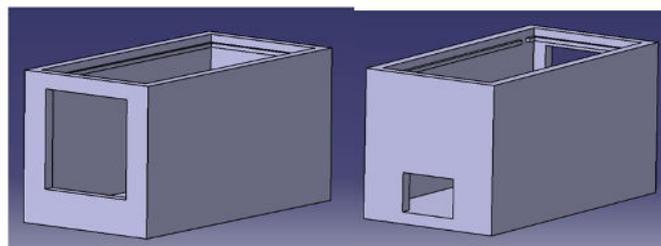


Figure 123: Illustrations of the case

On this second design, the hole for the power supply is now on the side. The whole case now looks like a brick rather than a tower. But if placed against a wall, it would stick out a lot. The tower shape was better, space-wise.

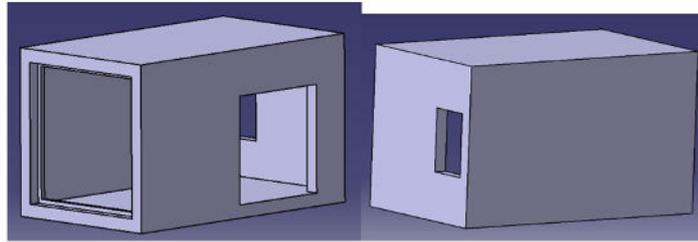


Figure 124: Illustrations of the case

That is why the 3rd and last design mixes all the best options from the two first tries to create the best case possible, considering the restrictions and dimensions that should have been respected.

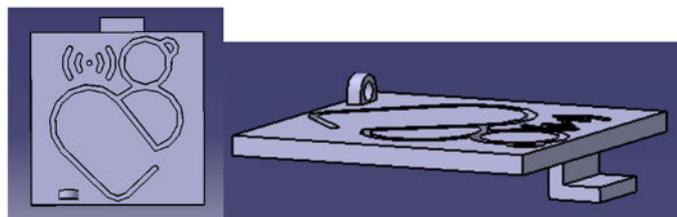


Figure 125: Illustrations of the lid

The logo, which appears on the lid, is for branding and communication. There is a lock on the bottom and a piece that sticks out on the top to help and take the lid off more easily.

8.1.2 Gas Sensor case

The gas sensor has the same needs and restrictions as the motion sensor. So on this one, only the shape of the hole for the sensor had to be adapted. The lid was also slightly modified so it would not come out as easily as it did on the first tries. There is now a hole in the case where the lock from the lid can just rest and close the box.

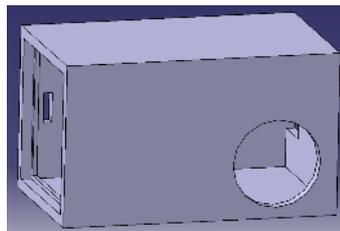


Figure 126: Illustrations of the gas sensor's case

Sensors such as the flame sensor or heat sensor followed the same process and only the hole in which the sensor had to stick out needed to be adapted.

8.1.3 Water sensor case

The water sensor has more restrictions. Indeed, the water cannot touch the wires or ESP32, otherwise it might shortcut the whole system, and damage the sensor. Therefore, the design needed to protect the ESP32 and the top part of the water sensor. To do so, we thought of silicone to seal the surrounding of the water sensors and keep the ESP32 out of the sink the sensor would be placed in.

This sensor is composed of three main parts: the water sensor case, where the actual sensor is located. The liquid needs to reach the water sensor, so there are many holes in the case to let it come in and then go out. The bottom of the case was designed with angles to facilitate the run of the liquid. The second part is the “body” of the case, where the ESP32 and other components that can’t go in the water are located. Finally, there is the “link case” that links and locks the two first parts together.

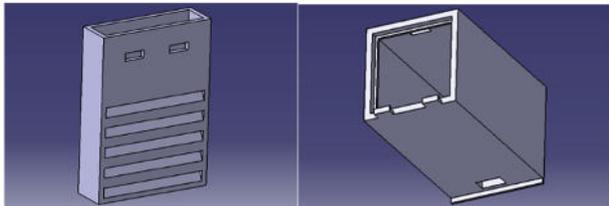


Figure 128: Water case - Body case

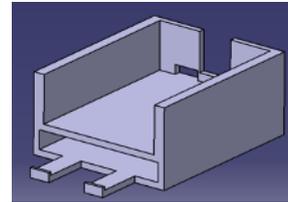


Figure 127: Link case

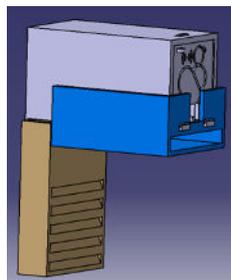


Figure 129: Water sensor case complete

Designing this case took longer than for the other ones as there are more parts to it, but especially because it was the first time a lock system between the parts was required. It took about 4 tries on each part to get the proper measurements.

In theory, measuring only requires a few tools and it is very easy and quick to get all the dimensions needed to design the cases so they would fit together. In reality, 3D printing makes it slightly more difficult, and less reliable. Indeed, the tolerances for a 3D printer are not precise, and they depend on the orientation the piece is built with. It also depends on where support is needed, because extra support will bring more material to the piece, which can sometimes be difficult to remove on the exact dimensions it was designed with.

For example, the link for the water sensor could be paced with those 2 different orientations:

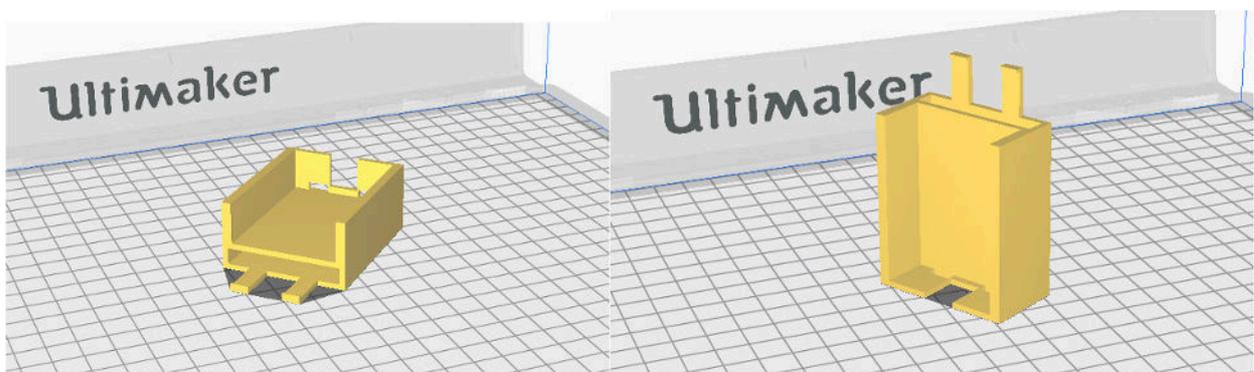


Figure 130: Water sensor: link part

The first one may seem more intuitive, as this is how it is going to be placed in the whole system, but the second orientation is actually faster, and cheaper, as it requires no support.

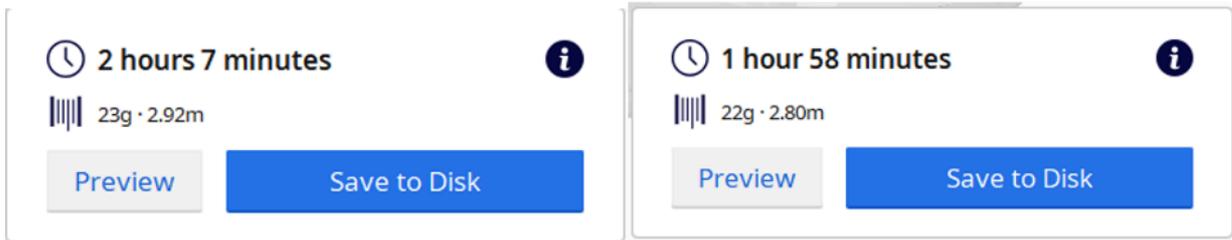


Figure 131: Time difference between two orientations

The difference may seem meaningless, but usually when 3D printing, there are several components printing at the same time. The time difference adds up, and it's frequent to save up to two or three hours on larger printing operations.

3D printing is a process very different from machining. When designing, it is essential to think about the product when it will be fresh out of the printer, especially concerning the supports. If it needs support, then there must be a way to remove the support once the printing is done. And if it is inside of the case, then there must be a hole large enough to use tools to remove it. That's why the water case was redesigned a few times before getting a final product:

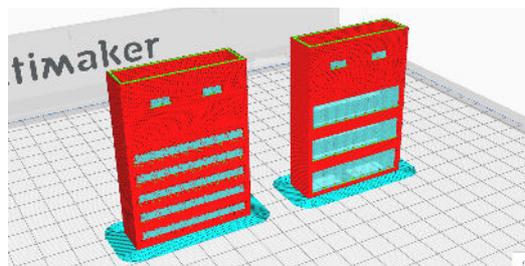


Figure 132: Water case design: front view

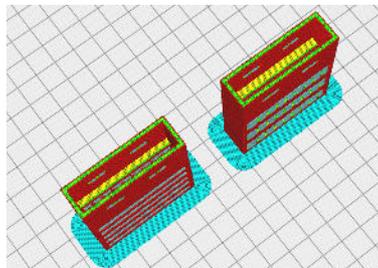


Figure 133: Water case design: top view

On the first version (left), the holes were too small to get the support inside, out. On the final one (right), everything was removed very easily.

In the end, giving each case a few tries and not getting it perfect the first time is part of the 3D printing process. Although it is very frustrating to lose time, material and money in every try, it is totally acceptable because 3D printing itself is a very cheap manufacturing process. Discussing with some of the responsible from the 3D printing laboratory, it was interesting to notice that even people working for months if not years with those processes still need a few attempts before actually getting their ideal product done. Knowing that nobody from our group had the occasion of working with this technology before this project, it is normal to learn from the mistakes. This wouldn't have been possible with other processes like machining, for cost reasons. Thanks to those first mistakes, the last cases were designed much faster than the first ones.

8.1.4 Temperature/humidity sensor

This case is simply a reshape of the motion sensor case, with an adapted hole for the sensor to come through.

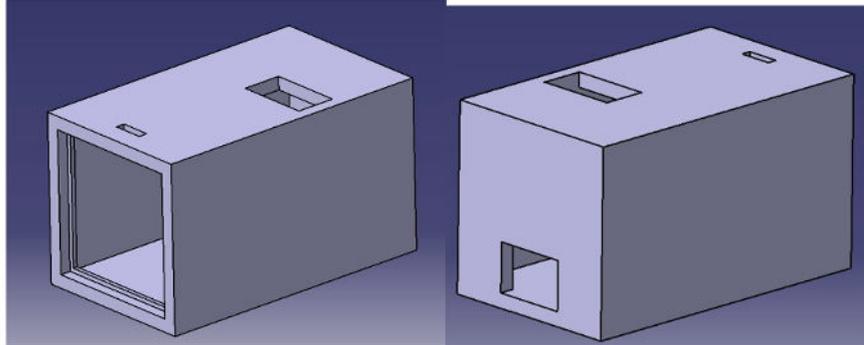


Figure 134: Temperature/humidity sensor

8.1.5 Flame/Light Sensor

This case was more delicate to design, because it is very small, and a component as big as a LED has to stick out. But the previous models were too small to fit the whole component and let the LED stick out on the side like the others. So, it had to stick in front, through the lid.

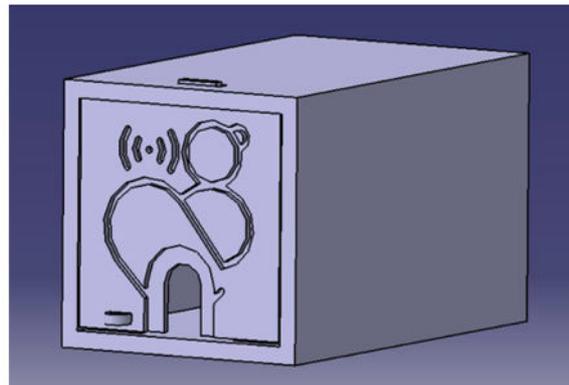


Figure 135: Flame/light sensor case

8.1.6 GPS Sensor

This case was the second most complicated one, as it needed two compartments. One for the ESP32, the GPS sensor, and extra components, and one for the screen where the coordinates needed to appear. Because the screen was flat, it was impossible to use the same trick as for the other sensors, where it stays in place thanks to its shape. For this one, it needed to be isolated with the exact dimensions of the sensor. But thanks to the many mistakes on the water sensor, it was easier to think of everything that could go wrong on this one and prevent all of the obstacles. That is why only one try was enough with the GPS sensor. Only the screen lid needed to be printed a second time to resize and adapt it better.

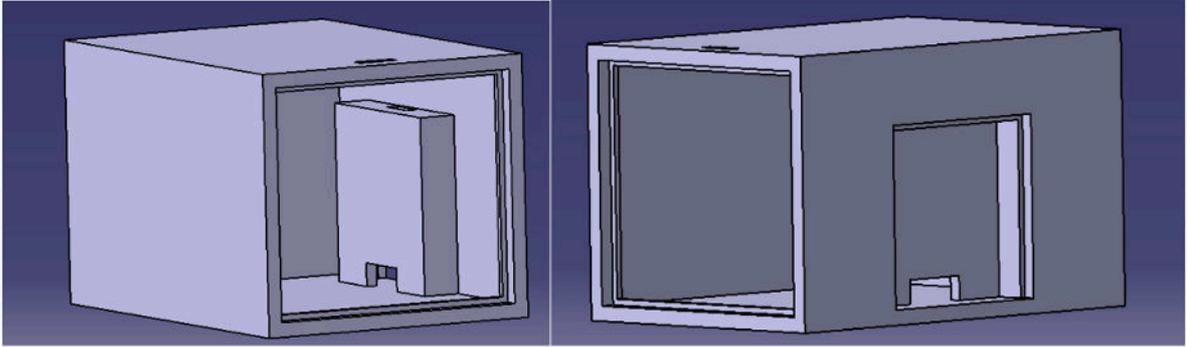


Figure 136: GPS body case

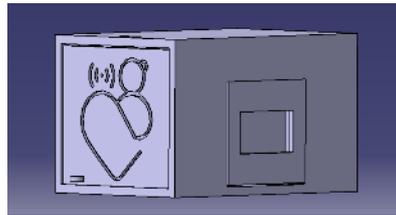


Figure 137: GPS Sensor case complete

9. Coding

9.1 Preparation

Before coding we need to look at the different scenarios which can occur and which our sensors can detect. Therefore, we made different cases and programming maps. For this we used a free program on the website: 'https://online.visual-paradigm.com'. All used programming maps were made with that software.

9.1.1 Case 1: Fire breaks out

The first case describes a fire inside the apartment. In this event, the fire sensor recognizes the fire and sends an output to the MQTT broker. When the fire is detected, a few measurements will be taken. The first is that a message will be written via telegram to the responsible person of the elderly. Afterwards, an alarm sound will be played via a buzzer to create an audio warning, the Phillips Hue lights will flash to indicate to the elderly person that something is wrong, and the smart plugs will be deactivated to ensure no other device interfering. If we receive a response via Telegram such as "STOP ALARM", we will know that the caretaker checked the situation and identified it as a false alarm or technical failure. Afterwards, the system goes again to the "start" and checks in 15 minutes again if there is a fire outbreak. If there is no fire detected, the system will go in standby again and the rest of the system will be reset.

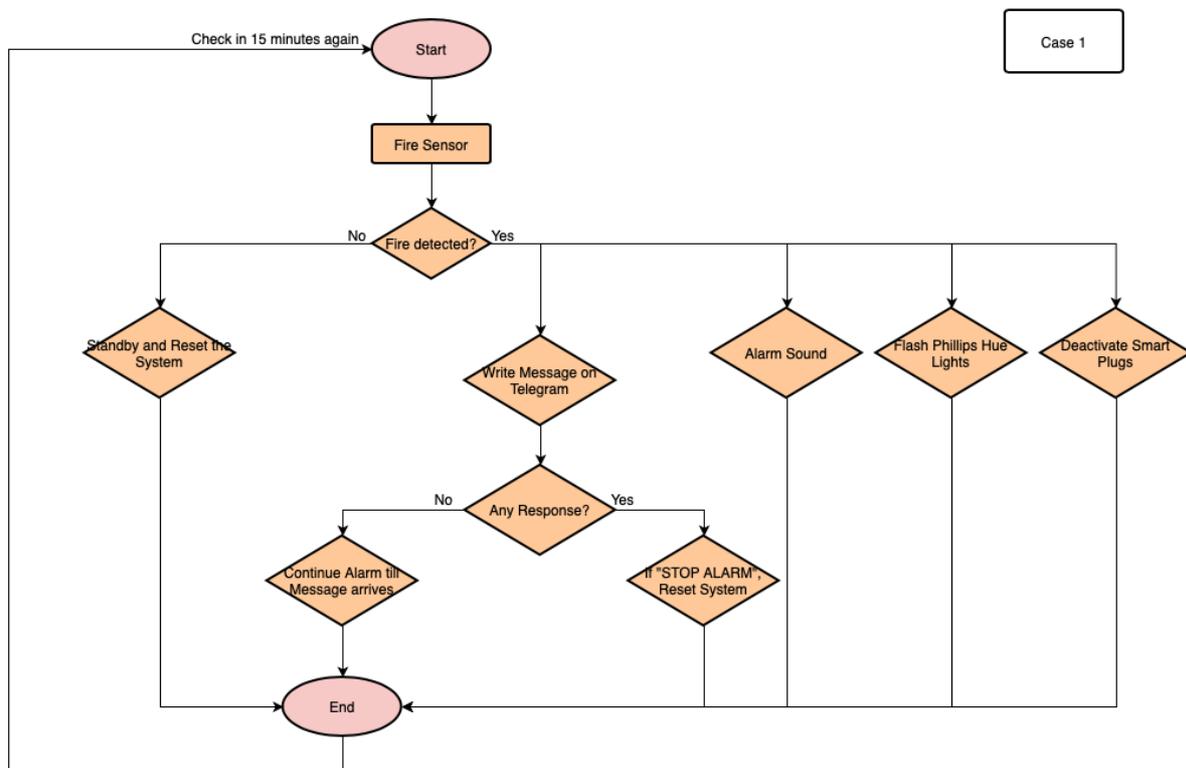


Figure 138: Programming map of case 1

9.1.2 Case 2: Person is unconscious

The second case is when the elderly person is unconscious or has not moved in a long time. The time is set to 90 minutes, within this time range the person has to move or an alarm will be

triggered. Four motion sensors will detect if there is any movement, afterwards the system asks the GPS sensor if the person is at home. If the person is at home, the system will reset and go into standby, since the person could be sleeping or laying on the couch. If the GPS signal does not detect something or is not at home, it will compare if the weight sensors recognize any weight on them, if there is nothing, they will just reset the system and go into standby. If they recognize any weight, they will send a message to Telegram, send an alarm sound, flash the Phillips Hue lights and deactivate the smart plugs for safety.

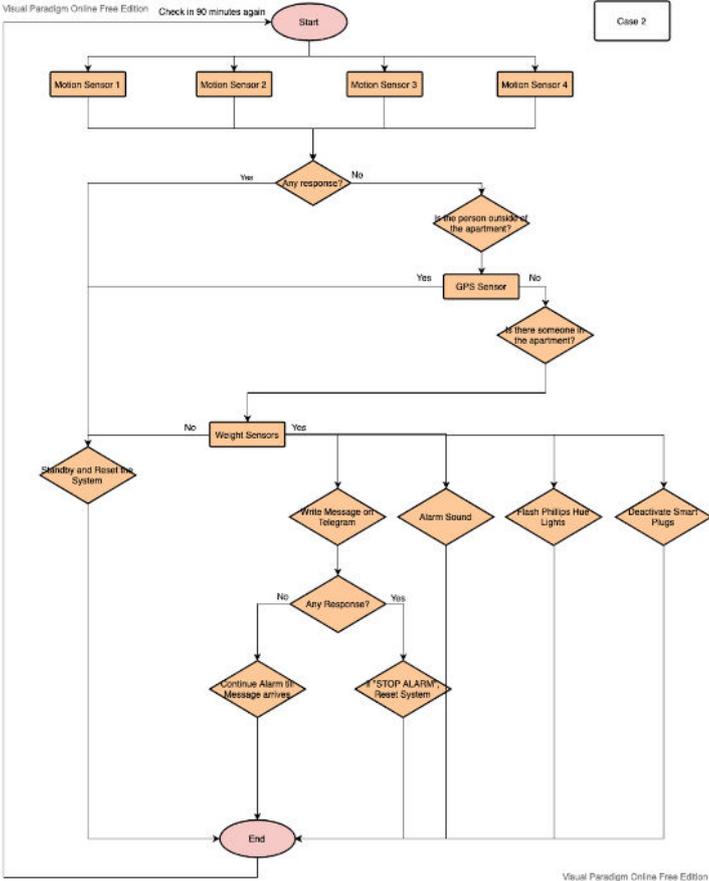


Figure 139: Programming map of case 2

9.1.3 Case 3: Water is overflowing

The possibility of water overflowing is a high risk. Therefore, the water overflow sensor will send an input and then the rest of the system will get triggered as seen before.

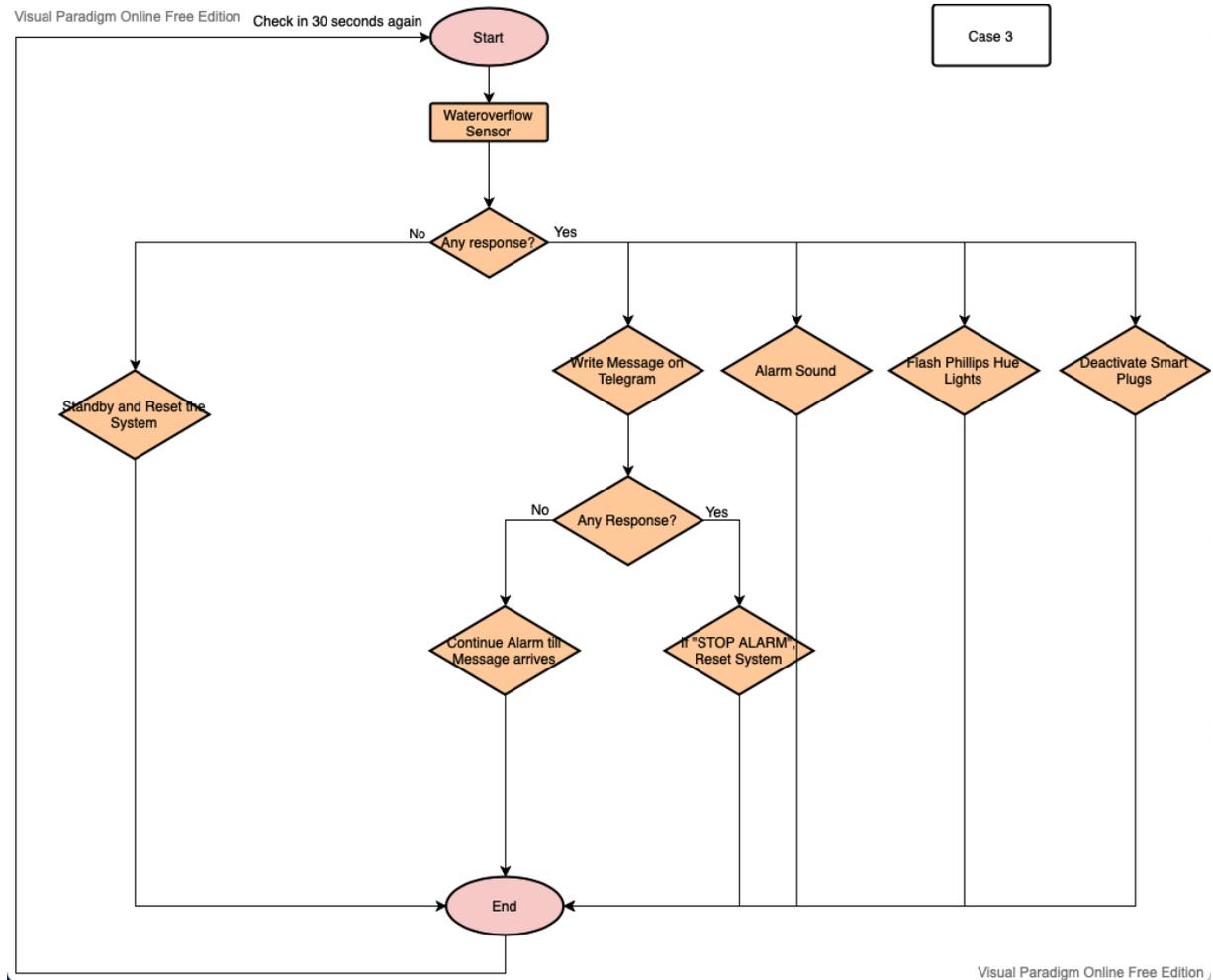
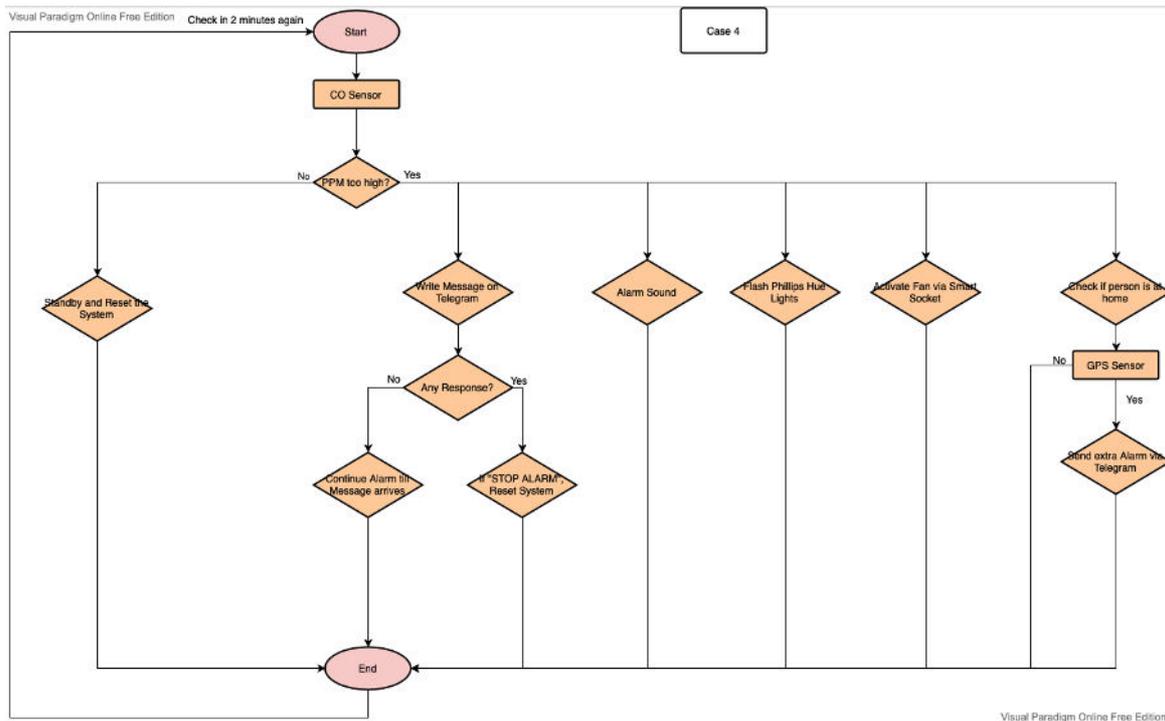


Figure 140: Programming map of case 3

9.1.4 Case 4: Ppm of CO is too high

The fourth case we have is when the CO level is too high. In this case the input of the CO sensor will be analysed and whether the PPM is over the recommended value. Afterwards a message via Telegram is sent to inform over the high CO level. Parallel, an alarm will be triggered, and the lights will flash. Also, the fan will be spinning by activating the smart socket. Furthermore, the GPS sensor gives us the information if the elderly person is inside the apartment or not. With this information extra messages will be sent via Telegram to ensure the guarantee of the safety of the person.



Programming map of case 4

9.1.5 Case 5: Too high or low humidity

The humidity sensor checks if the humidity is too high or too low. Depending on the value either the fan or the humidifier will be turned on via the proposed smart socket.

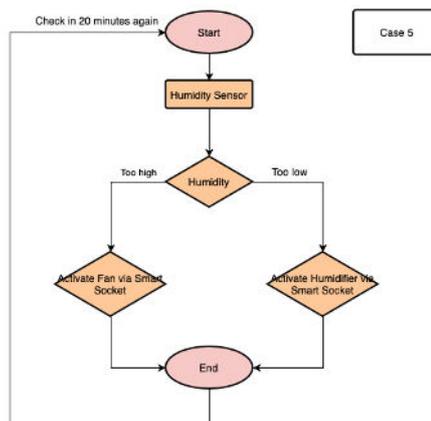


Figure 141: Programming map of case 5

9.1.6 Case 6: Too high or low temperature

In the 6th case, the temperature sensor informs us if it is too hot or too cold inside the room. If it is too hot, the system will activate the fan via the smart socket and check if the door is opened. If the door is opened, it will send a message via Telegram to try cooling down in other ways. If the door is closed, it will suggest opening it for better airflow and increased cooling. If the temperature is too low, the system will also check if the door is closed or opened. If opened, the system will suggest closing the door via Telegram. Otherwise, it will suggest warming up with different methods.

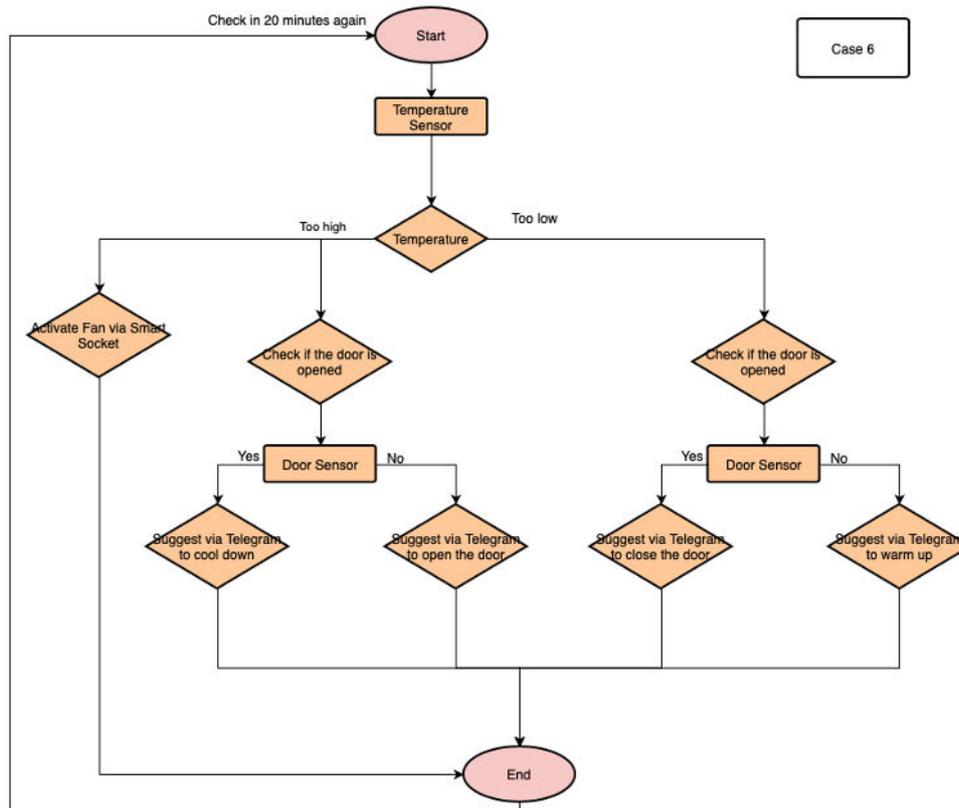
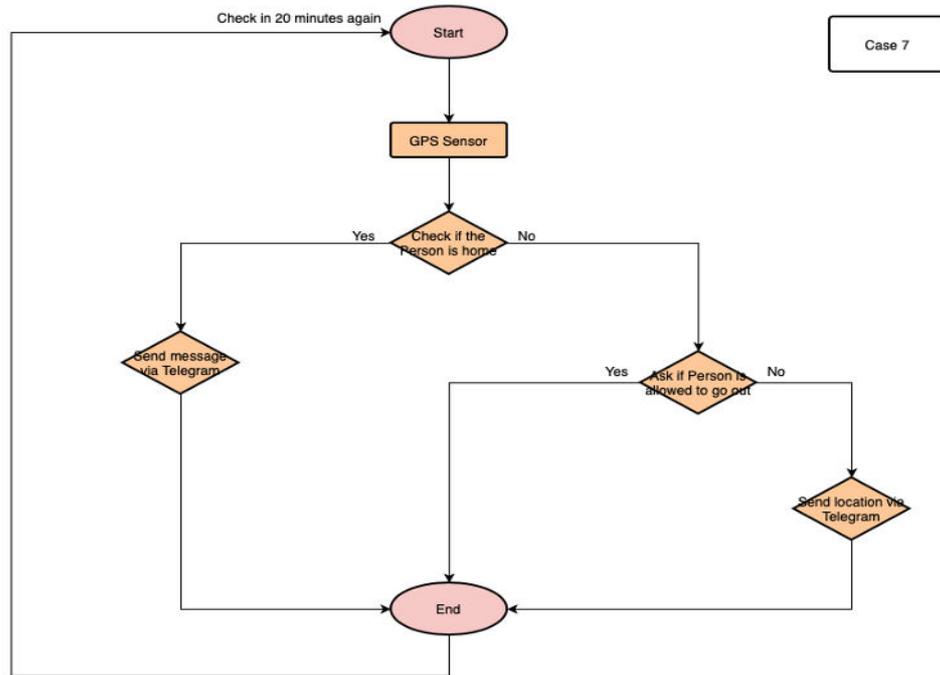


Figure 142: Programming map of case 6

9.1.7 Case 7: Person lost outside

The last case is if the person is missing and likely lost. In this case we check if the person is at home or not. If the person is outside, we will check if the person is allowed to do so by asking the caretaker via Telegram. If the person is not allowed, the next step is to get the latitude and longitude



via Telegram.

Figure 143: Programming map of case 7

9.2 Arduino Software

As explained earlier, we have different libraries included into our code for the ESP32's. In the beginning, we researched how we can connect the ESP32 to the WIFI. After figuring this out, we looked into how we can establish a stable connection within this network to the MQTT broker and Home Assistant.

To include a library, we need to write the code `"#include <library.h>"` with this the Arduino software knows which extra commands are embedded and which library needs to be loaded extra into the ESP32. The first one is PubSubClient, which gives us the tools for connecting and publishing to the MQTT broker. The second one is to get a stable internet connection.

This code was written and developed in collaboration with Eva Barceló Michans. The following is a basic code that can be used universally. In each ESP32 (sensor), this code has been modified to best implement the desired functions depending on the type.

```

#include <PubSubClient.h> // Connect and Publish to the MQTT broker
#include <WiFi.h>

//WiFi
const char* ssid = "W33-STUD";
const char* password = "██████████";

//MQTT
const char* mqtt_server="10.80.5.9";
const char* pressure_topic="/sensor/rain/1";
const char* mqtt_username="██████████";
const char* mqtt_password="██████████";
const char* clientID="rainsensor";

//Pressure sensor
int forcePin = 35;
int forceReading;

//Initialize WiFi and MQTT
WiFiClient wifiClient;
// 1883 is the port for the broker
PubSubClient client(mqtt_server, 1883, wifiClient);

```

Figure 144: Arduino code (1)

Afterwards we set constant characters to create the necessary information for the system. For the WiFi this includes the ssid or wifi name and the password. For the MQTT broker we need the server IP, the topic the sensor sends the gathered data to, the username and password for connecting and the clientID. The last one is for recognising the device in the network.

In the next step we defined the pins for the input of the sensor and a variable for processing the data.

Afterwards we initialize the WIFI and MQTT. We use the command WiFiClient to create a variable and later look if our connection with the MQTT broker is stable. If it's not stable, we will get a text message which will tell us why it didn't work.

```

void connect_MQTT() {
//Check connection to MQTT Broker
if(client.connect(clientID, mqtt_username, mqtt_password)){
Serial.println("Connected to MQTT Broker");
}
else{
switch(client.state()){
case -4: printf(" MQTT_CONNECTION_TIMEOUT - the server didn't respond within the keepalive time\n");
break;
case -3: printf(" MQTT_CONNECTION_LOST - the network connection was broken\n");
break;
case -2: printf(" MQTT_CONNECT_FAILED - the network connection failed\n");
break;
case -1: printf(" MQTT_DISCONNECTED - the client is disconnected cleanly\n");
break;
case 0: printf(" MQTT_CONNECTED - the client is connected\n");
break;
case 1: printf(" MQTT_CONNECT_BAD_PROTOCOL - the server doesn't support the requested version of MQTT\n");
break;
case 2: printf(" MQTT_CONNECT_BAD_CLIENT_ID - the server rejected the client identifier\n");
break;
case 3: printf(" MQTT_CONNECT_UNAVAILABLE - the server was unable to accept the connection\n");
break;
case 4: printf(" MQTT_CONNECT_BAD_CREDENTIALS - the username/password were rejected\n");
break;
case 5: printf(" MQTT_CONNECT_UNAUTHORIZED - the client was not authorized to connect\n");
break;
}
//Serial.println("Connection to MQTT Broker failed");
}
}
}

```

Figure 145: Arduino code (2)

In the next step we connect to the WIFI and check if the connection is stable. If there is a problem within the connection, we will also get a text message and the system will try to connect again.

```

void setup() {
  Serial.begin(9600); // We'll send debugging information via the Serial monitor

  //Check connection to Wifi
  Serial.println();
  WiFi.begin(ssid, password);
  Serial.print("Connecting to WiFi");
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println();
  Serial.println("Connected to the WiFi network");
  Serial.println(WiFi.localIP());
  connect_MQTT();
}

```

Figure 146: Arduino code (3)

The abovementioned parts of the programming were considering the WIFI connection and establishing the connection to MQTT and the clientID. However, the most important part of the code considers the sensor and its output. During the project, we were working with two types of sensors with either analog or digital outputs. Therefore, two different approaches to writing the codes had to be taken.

However, before going into coding details, the contrast between analog and digital output ought to be explained and also which sensors used in the project give the respective outputs.

Analog output means that the signal given by the sensor is directly proportional to the measured signal¹⁸⁴. In simpler words, the output can be of any value within the given range. The analog sensors used in the project are as follows: pressure, temperature, humidity, rain, and gas sensor.

Digital output means that its value is a discreet one - it is only 0 or 1.¹⁸⁵ The digital sensors used in the project are as follows: motion, fire, and light sensor.

```

void loop() {

  forceReading = analogRead(27);
  Serial.println(forceReading);
  delay(100);
  forceReading = analogRead(forcePin);
  //Serial.print("Analog reading = ");
  //Serial.println(forceReading);
  //if (forceReading>0){

  if (client.publish(pressure_topic, String(forceReading).c_str())){
    Serial.println("Analog reading = ");
    Serial.println(forceReading);
  }
  else {
    Serial.println("Status failed to send. Reconnecting to MQTT Broker and trying again");
    client.connect(clientID, mqtt_username, mqtt_password);
    delay(10);
    client.publish(pressure_topic, String(forceReading).c_str());
  }

  delay(5000);
  //}
}

```

Figure 147: Code for analog sensors

Notwithstanding, let us now focus on the explanation of the codes for analog and digital sensors, respectively.

¹⁸⁴ <https://iot4beginners.com/analog-sensors-vs-digital-sensors/>

¹⁸⁵ <https://iot4beginners.com/analog-sensors-vs-digital-sensors/>

Firstly, we need to start with the 'void loop()' function which Arduino uses as a part of its structure. It is an important function because it enables the code to run as long as the board - in our case ESP32 - is on.¹⁸⁶ Afterwards, the type of input - analogRead - and the number of the pin on the ESP32 board - 27 - are defined. The function 'Serial.println' displays the reading of the sensor.¹⁸⁷ The 'delay' function sets the time between displays of the reading of the sensor and by adding the number in the brackets, we are able to modify this time and customize it.

After defining the pin and type of the reading, the 'if/else' function is utilized which enables it to introduce the conditions to the code. In this case, after the 'if' function, firstly the 'client.publish' is included to publish the output in the Home Assistant, and secondly the 'Serial.println' ("Analog reading = ") which is for the display of actual value from the sensor. When it comes to the 'else' function, it takes into consideration what happens when the connection with MQTT fails. Once again, also the 'delay' function is used to adjust the time between the displays.

```
int motion_sensor = 34;
int motion_detected;

void loop()
{
  pinMode(motion_sensor, INPUT);
  motion_detected = digitalRead(motion_sensor);
  Serial.println(motion_detected);

  if (motion_detected == LOW)
  {
    Serial.println("no motion detected");
    (client.publish(motion_topic, String("no motion detected").c_str()));
  }
  else
  {
    Serial.println("motion detected");
    (client.publish(motion_topic, String("motion detected").c_str()));
  }
  delay(500);
}
```

Figure 148: Code for digital sensors

Now we can proceed to the explanation of the code for the digital sensor - in this case the presented code was used for one of the motion sensors. As standard, the code starts with the 'void loop()'. The next thing included in the code is 'pinMode' which configures the specified pin to give either an input or output - in this instance it is specified for the given sensor that the pin gives an input.¹⁸⁸

Afterwards, the variable was defined (motion_detected) and what type of read it is [digitalRead(motion_sensor)] and once again the 'Serial.println' function with the proper variable is written. Later, the 'if/else' function is used once again to create conditions. Unlike analog signals, which as it was stated before taking on any value within a range of values, digital signals have only two distinct values: high (1) or low (0).¹⁸⁹

¹⁸⁶ <https://www.letsstartcoding.com/syntax/>

¹⁸⁷ <https://www.arduino.cc/reference/en/language/functions/communication/serial/println/>

¹⁸⁸ <https://www.arduino.cc/reference/en/language/functions/digital-io/pinmode/>

¹⁸⁹ <https://www.allaboutcircuits.com/projects/learn-how-to-use-the-arduinos-digital-i-o/>

Here, we use digital signals in situations where the input will have one of those two values - therefore in this situation if the input we get is 'low' (equivalent to 0) then the motion is not detected. Similarly with the situation when the input is 'high' (equivalent to 1) - the motion is then detected. In both cases, the information needs to be published in the node-RED, therefore the functions 'client.publish' with proper topic and string of what the displayed information, are applied.

The codes for other digital and analog sensors were written using the same principles as described above, with the differences in MQTT topics and what information is to be displayed in the Node-RED.

9.3 Node-RED

In the Node-RED for Home Assistant a lot of plugins are preinstalled. Despite the number of plugins, we installed a few more for our project. We installed: Telegram, Philips Hue and Smart Socket as plugins. After installing the necessary extras, the coding was divided into 2 phases. The first phase is declaring all inputs from the sensors. The second phase is to process the given data.

9.3.1 Phase 1: Initialization

First all MQTT inputs are needed, and it creates a combined message with them. For this purpose, a join-node was used. It is used to create a combination of the different inputs you can see on the left. Before the join-node every input needs to be accessed separately, with this one we can pick the information we need with a simple line in the code. In the join node we also set the number of message parts that should be included. This number is the quantity of our sensors. Afterwards this combined message will be sent to a function-node in which we write a JavaScript code that sets the global variables.

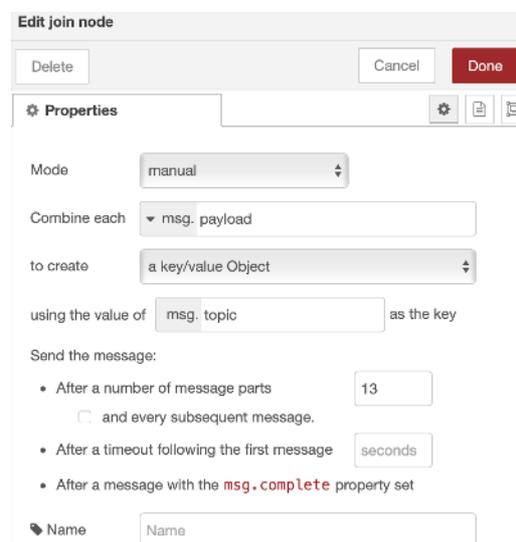


Figure 149: Join-node

On the left side are all our different sensors, which are connected via MQTT. When an input comes from one of them, the message will be directed to the join-node, which sums up all the given information in one message. Afterwards, this message will be sent to a function-node, which will declare global variables to be used in other parts of the code.

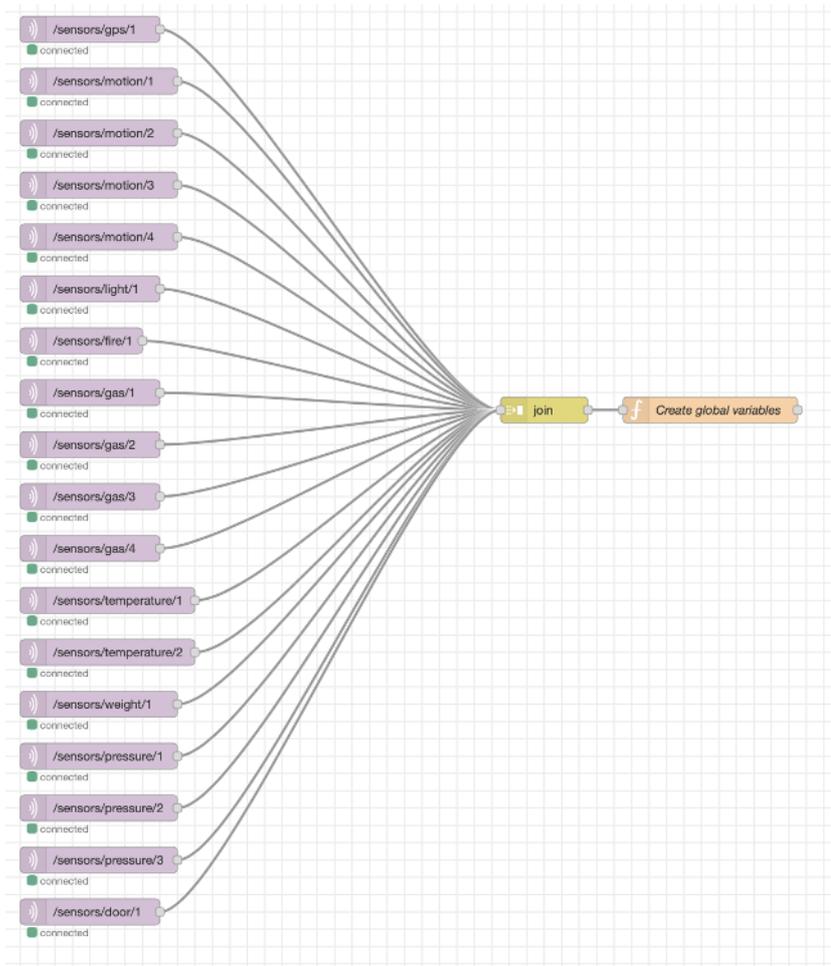


Figure 150: Node-RED (1)

Here is an example how the definition of the global variables looks like. Each variables gets their own name to be found later on. Also, each of these needs a value, which we provide with the information from the join-node.

```

1 global.set("sensor_gps_1", msg.payload["/sensor/gps/1"]);
2 global.set("sensor_motion_1", msg.payload["/sensor/motion/1"]);
3 global.set("sensor_motion_2", msg.payload["/sensor/motion/2"]);
4 global.set("sensor_motion_3", msg.payload["/sensor/motion/3"]);
5 global.set("sensor_motion_4", msg.payload["/sensor/motion/4"]);
6 global.set("sensor_light_1", msg.payload["/sensor/light/1"]);
7 global.set("sensor_fire_1", msg.payload["/sensor/fire/1"]);
8 global.set("sensor_light_1", msg.payload["/sensor/light/1"]);
9 global.set("sensor_gas_1", msg.payload["/sensor/gas/1"]);
10 global.set("sensor_gas_2", msg.payload["/sensor/gas/2"]);
11 global.set("sensor_gas_3", msg.payload["/sensor/gas/3"]);
12 global.set("sensor_gas_4", msg.payload["/sensor/gas/4"]);
13 global.set("sensor_temperature_1", msg.payload["/sensor/temperature/1"]);
14 global.set("sensor_temperature_2", msg.payload["/sensor/temperature/2"]);
15 global.set("sensor_weight_1", msg.payload["/sensor/weight/1"]);
16 global.set("sensor_weight_2", msg.payload["/sensor/weight/2"]);
17 global.set("sensor_weight_3", msg.payload["/sensor/weight/3"]);
18 global.set("sensor_door_1", msg.payload["/sensor/door/1"]);
19
20 return;

```

Figure 151: Node-RED (2)

9.3.2 Phase 2: Processing

In the second phase we have on the left side inject-nodes, which will inject in different intervals a message to activate the function-node to which they are attached. Afterwards the output from that node goes into switch-nodes, which inspect the input and classify it depending on its value. In our case we used numbers for each case and situation.

Later in that stage we send the output from the switch-node to the nodes from our devices. In our case these are the buzzer, Philips Hue lights, Smart Plugs and the Telegram bot. For the Philips Hue

we have installed the needed nodes which will turn on and off the lights depending on the input. The buzzer will receive its command via MQTT, and the Smart Plugs also work with an installed node to turn them on and off. The output for Telegram needs to be send to a general function-node for all cases, since the Telegram bot needs to send different messages depending on the situation.

After the switch-nodes, which are labeled as “Buzzer”, “smartplugs” and “philips Hue” we add change-nodes depending on the situation. The change-nodes change the input. For example, we can change the received 1 to a “ON” so the Hue Light can read the input and process it. Afterwards we delete the msg.topic since this causes problems when the smart device wants to read the input. Directly after the device we put a function-node which saves the current state of the object: ON or OFF.

There is also a Hue Switch inbound, which will deactivate all lights.

In the following we will demonstrate the steps by one example from the cases, since most of them are written in a similar way with little changes. We choose the case 1: fire.

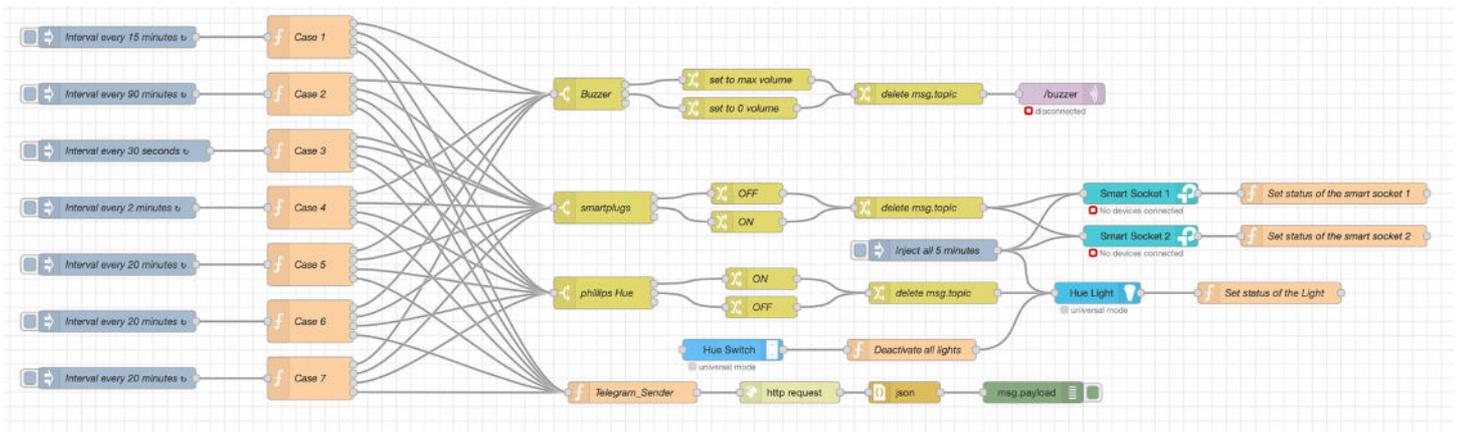


Figure 152: General overview of phase 2 (1)

```

1 var fire_sensor_1 = global.get("fire_sensor_1"); //get the current state of the sensor
2 var telegram_message_answer = global.get("telegram_message"); //get the current message input
3
4 if(fire_sensor_1 == "Fire detected!"){ //if fire is detected
5   if(telegram_message_answer == 3){ //check if the Alarm is deactivated
6     return;
7   }else{
8     buzzer = {payload:1, topic:"buzzer"};
9     smartplugs = {payload:1, topic:"smartplugs"};
10    hue = {payload:1, topic:"huelights"};
11    telegram_message_send = {payload:1, topic:"Telegram"};
12    return[buzzer, smartplugs, hue, telegram_message_send];
13  }
14 }else if(fire_sensor_1 == "No fire detected!"){ //if no fire is detected
15   buzzer = {payload:2, topic:"buzzer"};
16   smartplugs = {payload:2, topic:"smartplugs"};
17   hue = {payload:2, topic:"huelights"};
18   telegram_message_send = {payload:4, topic:"Telegram"};
19   return[buzzer, smartplugs, hue, telegram_message_send];
20 }else if(msg.payload == 1){ //when the inject sends 1
21   return;
22 }else if((fire_sensor_1 != "Fire detected!")&&(fire_sensor_1 != "No fire detected!")){ //any other input which means its broken
23   buzzer = {payload:0, topic:"buzzer"};
24   smartplugs = {payload:0, topic:"smartplugs"};
25   hue = {payload:0, topic:"huelights"};
26   telegram_message_send = {payload:2, topic:"Telegram"}; //when something different gets send
27   return[buzzer, smartplugs, hue, telegram_message_send];
28 }

```

Figure 153: Code for case 1 - function

The switch-node for the buzzer checks then if the input is 1/2/0, depending on the state.

Output	Meaning
1	Fire detected!
2	No fire detected!
0	Sensor malfunctioning!

Figure 154: Outputs for case 1 - buzzer



Figure 155: Buzzer

Now we want to look at the Telegram bot, which sends a message if a specific number is send. The numbers are following:

Output	Meaning
1	Fire detected!
2	Sensor malfunctioning!
3	Firealarm was deactivated!

Figure 156: Outputs for case 1 – Telegram

The function-node receives the input and gives as an output the message which will be send via Telegram. In the following an example for the fire alarm.

```

1 var input = msg.payload;
2 var output;
3 if(input == 100){ //100 = default by me
4   return;
5 }else if(input == 1){
6   output = {payload: "Warning Fire in the housing. Please write Stop Firealarm to end alarm!", topic: "fire_sensor_1"};
7   return output;
8 }else if(input == 2){
9   output = {payload: "Fire Sensor is sending not readable data. Please restart or disconnect from the system.", topic: "fire_sensor_1"};
10  return output;
11 }else if(input == 3){
12  output = {payload: "Firealarm will be deactivated. Asking in 30 minutes again, if still sensing a fire.", topic: "fire_sensor_1"};
13  return output;

```

Figure 157: Function-node messages for Telegram

We also implemented a Telegram receiver, which looks at the received message and creates a global variable to work with in the previous steps. Furthermore, we also integrated a counter for the 30 minutes interval. The message receiver adds one number to a counter and if it reaches 2 it sets to zero again, which is meaning that the 30 minutes timer is over.

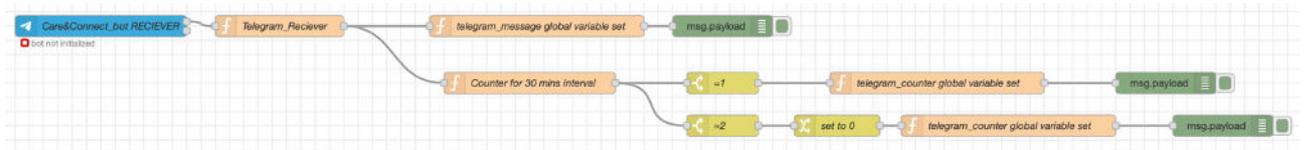


Figure 158: General overview of phase 2 (2)

9.3.3 Telegram

The Care&Connect bot will send messages like below, which can be answered.



Figure 159: Telegram bot

10. Communication and promotion

In addition to a good corporate identity, it is important to know how to communicate. To do this, it is necessary to understand how to convey information, educate and seduce the targets. Once the elements are known, it is possible to develop several means of communication.

10.1 Advertisement

The first question is thinking about how to advertise and educate the targets?

Elderly

How to advertise towards senior generation^{190,191}

Our main target group for this project is the senior generation and we have to trigger this target group to buy our product and/or make them understand what it does and how it can provide help for them.

In this search to explain and/or sell our ideas we have to take in consideration how we should advertise our project to them. Since not every generation has the same feelings or tastes about one subject, we have to research how to advertise to them and what advertisement speaks to them.

This can be said in 5 steps:

¹⁹⁰ <https://smallbusiness.chron.com/advertise-elderly-11884.html>

¹⁹¹ <https://www.semrush.com/blog/7-tips-for-marketing-effectively-to-seniors/>

1. Be respectful, it is easy to say that your target group is elderly, but this word has a negative connotation, saying that they are frail and weak. So, we will mention them as seniors.
2. The use of general media (advertisement via radio, tv, papers, flyers and mostly printable) should be used since elderly are not that engaged in the new world of social media.
3. The size of our text should be put in perspective too, elderly people tend to have a bit more problems with reading so we should take into consideration that the text is easily readable.
4. The use of nostalgic references of their time should help too.
5. And last, the quickest way of dispersing your media in a quick way is to get in contact with senior centers or nursing homes. You can easily organize an event there for a small fee or by giving them free products.

Nurses' students

The goal is to figure out how to educate and inspire students to put sensors in the homes of seniors with the help of a room. In a class it is easier to educate people, where one can interact with students.

However, the main problem with the project is that there will be no one to explain the principle of the sensors, how they work and why they are useful.

We should also bear in mind that the target is students, who are able to think and stand back from what they are going to read and learn. Various studies have shown that students learn more easily by practicing and discovering than by simply learning the lectures. Their curiosity is amplified, and they want to understand more things in order to achieve more things¹⁹².

The idea that comes closest to a place where you go to learn by yourself, where there is not necessarily someone to explain and where you have to obtain appropriate data by yourself, are the museums.

It is therefore interesting to try to understand how they can captivate young and old, but especially how they deliver their information. So, the goal is to mix two effective solutions: the way students are educated and the way the information is given in a museum.

The best way to do it is using videos, sounds or graphics. Interaction is the keyword to catch the attention of people and educate them at the same time to entertain¹⁹³ them.

But how to make this room more interactive?

First of all: do not put all the information in the same place.

Students are people who spend a lot of time reading, whether these are articles, books, publications, etc. Having written too much on one panel, may seem to be scary and discourage to learn¹⁹⁴. The communication needs to be light and enjoyable. For this reason, the first step is to separate the information - but how?

For communication to be effective, you need to work in a funnel system. That is to say, you have to dilute the information in several ways: first of all, some brief information, graphics, sounds, illustrations. Elements that are simple to understand and do not require too much thought.

Then, we can use a second communication medium to give more information, more detail without overwhelming the reader with the amount of information.

Finally, for the most interested people, we can provide the possibility to have access to more information. They can be accessible on cards arranged, company names, etc. This last step is called "non-invasive" and must remain discreet.

¹⁹² Course on teaching and the philosophy of teaching - University of Grenoble - Master 1 of education

¹⁹³ <https://edservices.wiley.com/5-ways-incorporate-media/>

¹⁹⁴ La communication visuelle - Visual communication - University of Chambéry

In the second place, all this information must be organized in the space. The goal is that they do not seem to be obstructive.

Within the framework of the project, we have chosen to bring the information in the form of posters. Only the essential information will be written on them: the students do not need to know everything about the functioning of a sensor. They only need to know what it will bring to the patient and to their profession and how these sensors can improve the daily life of everyone.

10.2 Social media

To share our project and communicate it to a larger audience, social networks have been created.

We used the platform Instagram and Facebook which allow us to have visibility.

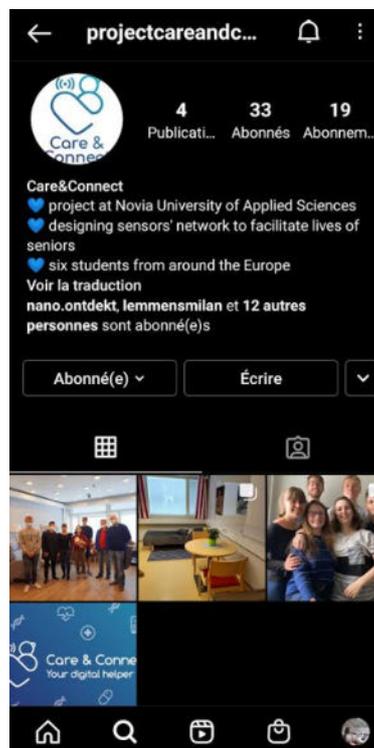


Figure 160: Front page of the account of the project

To make it dynamic we made different posts such as the presentation of the project, the team that composes the project, the simulation room or the visit to Vamia.

For each post hashtags were used to reference the post and make it attract more views. As soon as we can we also post stories like the reception of the sensors, the group working and many more.

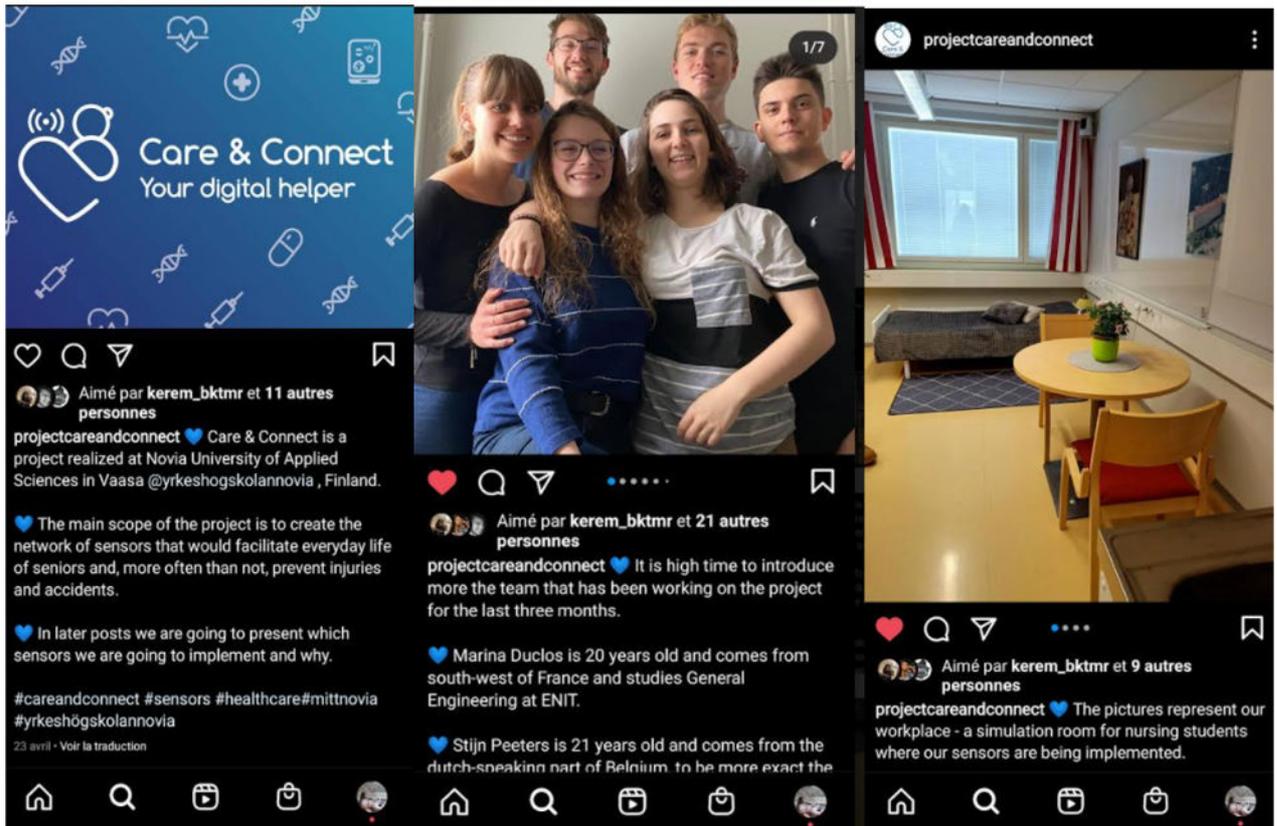


Figure 161: Screenshots of different publication made on the Care & Connect account

The Care & Connect Facebook page follows the same idea by mirroring Instagram posts. These two interfaces do not reach the same audience and users do not have the same habits. Communicating on these two interfaces allows us to reach a wider audience.



Figure 162: Screenshot of the banner of the Care & Connect page

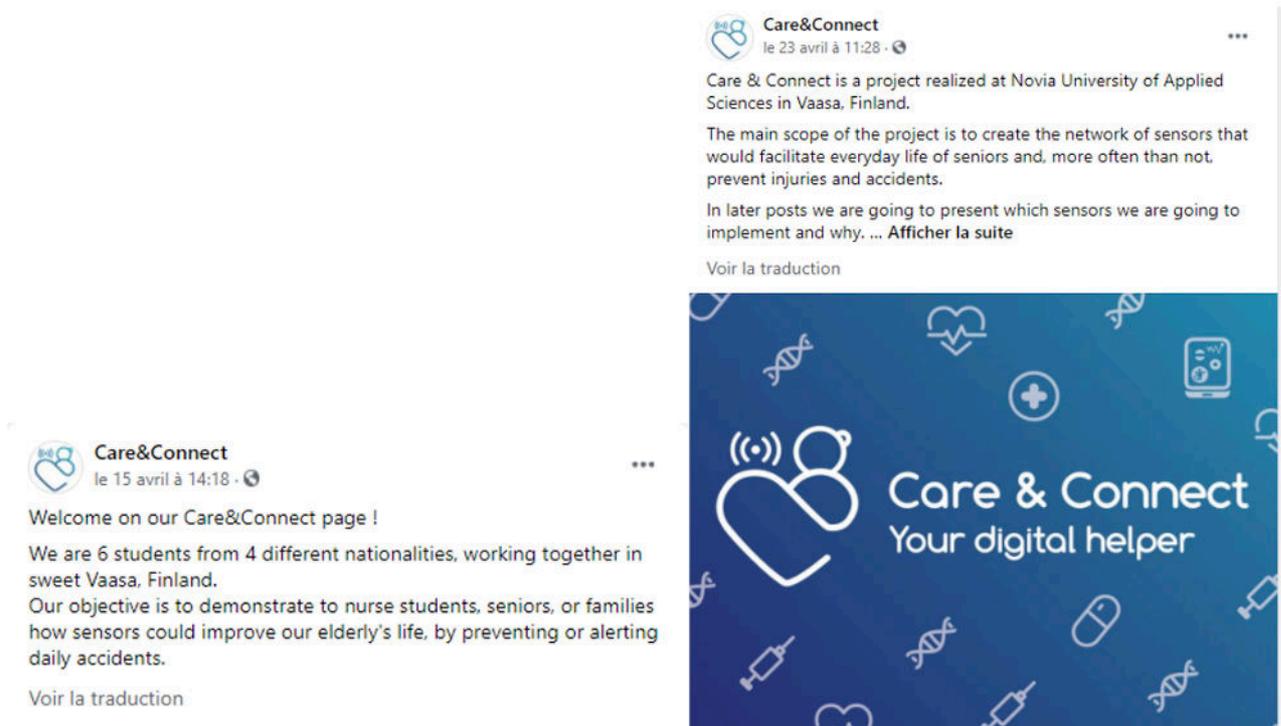


Figure 163: Screenshots of publications on the Facebook page

10.3 Key chains

In order to remain in the memory of the students we thought of key chains. In this way, they will have something that will remind them of the project and the sensors in their daily life with a keychain.

It is also a good way for them to advertise and promote the project on their own.



Figure 164: Picture of the printing of the key chain

The school gives the students free access to the 3D printing machines, so it made sense to use them to manufacture the key chains.

As for the cases, the design was created on Catia, recreating the logo on the software, and designing the plaque that would support it, thinking of the hole for the keychain ring, etc. Different designs were created before settling on the final one.

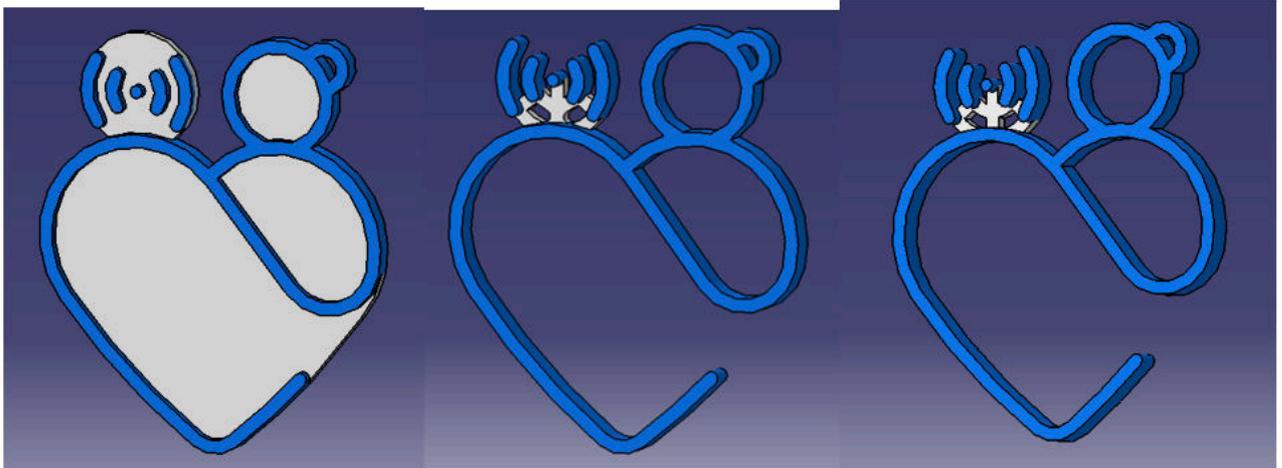


Figure 165: Illustrations of the different design for the key chain

In the end this was voted as the final design:



Figure 166: Final design of the key chain

About 20 keychains were printed. Unfortunately, blue was not available, so it was impossible to have a two-coloured keychain for now, with the part of the background in white and the part in volume with the shape of the logo in relief in blue. But as soon as the stocks are refilled, it would not take long to have two coloured keychains, as the files are already available on our drive.

10.4 Displays

Different displays have been thought of:

- one that can put at disposal the key chains
- one that can display and contain the flyers

In order to make the communication method effective we were interested in the existing types of displays. Speaking about the key chains, there are different ways: either hung, or placed in a completely open box, or in a box with a slot like a dispenser. The solution with hanging key chains offers less communication possibilities and the structure cannot be modified if one day you want to distribute other communication goodies. The closed box system gives a more "gift" and more "precious" aspect because it is slightly closed. But it discourages the person from taking the goods.

Finally, for the open box two options exist. A flat box with several levels which gives the impression of a store shelf and therefore gives value to the key ring. The second option is the flat open box with only one floor which will make the key ring more commonplace by making it accessible.

Our final design for the display looks like this:



Figure 169: Final display

10.5 Flyers

Every project wants to promote their end product in as big a way they can. This is frequently done through online media platforms, websites and email promoting. But why not use the original advertisement method, the flyer, is as good as a well-defined website and should not be excused.

Why a flyer?

Flyers are a simple and powerful approach to educate individuals on the road regarding your project. They may have never seen your site or may not be on social media. Regardless of whether they are on the web, they may take more notice of a flyer that is given to them as opposed to looking through their already full online notification feed, such as emails, advertisement, and social media. On top of that is the problem that our attention span is getting lower due to the quick and snappy online world. This means you will need to get the attention of the reader really quick, and a flyer is a speedy method of catching the eye.

How do you get the attention?

You need to require some planning and time for your flyer. A planned and printed flyer will establish a greatly improved first connection than a manually written one, and the initial feeling truly matters.

This can be done by first knowing to whom and what you are going to advertise and creating a good corporate identity in which you explain the consumer, the design, the colors, the fonts, and the usage of this all together. Once you have got these building blocks you can figure out what or how you can create the right flyer that you require.

Pick the main concerns.

It is fundamental that you make yourself clear, and that this data is fast and simple to understand. We are more likely to read a flyer when it highlights striking and big font size, rather than little, small font sizes. Keep it short and to the point, and most importantly let your organization stand out by using your organization logo.

The flyer for Care & Connect.

The main priority is laid in informing the reader of how the project works and what has been accomplished, but most importantly explaining instantly for what we stand for. This is done by the graphic elements such as photos, patterns, and icons. If you look at the flyer you immediately see that it is about innovation and healthcare.

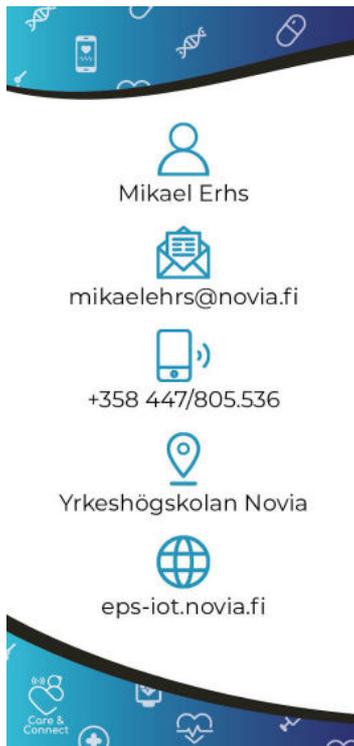


About

Care & Connect is a project realized within the European Project Semester program at Novia University of Applied Sciences in Vaasa. For 4 months, the group of six students from around the Europe has been working on development of a novel technology that could be used in homes of seniors. The main goals of the project were as follows:

- ♥ Choosing appropriate sensors;
- ♥ Implementing them in the simulation room;
- ♥ Creating the network of interdependent sensors;
- ♥ Introducing the technology to nursing students and future healthcare workers;
- ♥ Providing safe environment and independence for seniors in the future;
- ♥ Designing of the packaging for the sensors;
- ♥ Inventing corporate identity of the project.

Figure 171: Final design front flyer



Our mission & vision

Our mission is the development of a healthcare and accident prevention system for elderly or disabled people. This to educate future medical workers what is possible but also improve their skills.

Our vision to achieve this project is to create a network of multiple sensors that recognizes accidents and prevents further injuries by informing responsible people. This by creating such a system, a lot of subsequent injuries can be prevented, lives can be saved, and a sense of security can be restored.

Sensors

Sensors available in the simulation room at the moment are.

- ♥ Door & window sensors
- ♥ Fire sensor
- ♥ Gas sensor
- ♥ GPS
- ♥ Humidity sensor
- ♥ Motion sensors
- ♥ Pressure sensors
- ♥ Temperature sensor
- ♥ Weight sensor
- ♥ Water overflow sensor

Figure 170: Final design back flyer

10.6 Posters

Posters are a great way to communicate your project because it showcases the main information of your project in a quick and easy way to a big group of people.

This media form is one of the best ways to communicate to a broad group of people because even people who you are not aiming to convince get to see it and might get interested. Achieving this is quite hard in this online world where the attention span gets lower and lower. This is why you have to grab the attention of the reader in less than a second and get them interested in the information you want to communicate.

Advantages of posters

The advantage of grabbing the attention in a second is the main reason why you should use a poster.

Even though you might think that because of social media people are not interested in the surroundings around them. You are quite wrong, when you're walking or just wondering about something in public, you're unpurposefully looking around you. And this is exactly the moment when the poster will strike and get the attention of the consumer.

Certainly because it is bigger than a flyer and a smaller size than a billboard, it makes the poster reach a broader group of people. The amount of people you will advertise to depends on how long you keep your poster hanging outside. However, there is a limit in how long you can leave them hanging, if they are hanging there too long the consumer will start blocking out the poster.

As said before, you should always make the design consistent so that the consumer can instantly see from which corporate or business the poster comes. This comes back to the corporate identity and that is why the corporate identity is so important in the creation of multiple different kinds of media. When the consumer sees the poster and later sees the website, flyer, and or other media they instantly subconsciously know which corporation, or brand is advertising to them.

The posters for Care & Connect.

For this project there are three posters, which can be differentiated in two groups: the attention group and the information group. As you might have guessed, the attention poster is the first poster, the big picture and colorful display grabs the attention while the other two posters are mainly to convey the information about the sensors over to the reader.

The reason why the posters are made like this, is so that the reader gets interested at first and once you have the attention of the reader, you can communicate all the important information to them.

This by guiding their eye, as you may notice on the posters of the information group you see some graphic elements and cartoons. Their objective is to guide the reader through the poster but also make the poster feel lighter and easier to consume.

These graphic elements and cartoons also have an underlying message, they convey the message of how our system works. At first you see the hand with the health monitor bracelet around his arm which leads to the cloud that represents the computer where data is registered. From there on out it goes over to the main hub or the tablet where the elderly person or nurse can read out the data and after that it goes to the phone which will get notification when the elderly person has fallen or needs help.



Care & Connect
Your digital helper



Introduction

Care & Connect is a project realized within the European Project Semester program at Novia University of Applied Sciences in Vaasa. For 4 months, the group of six students from around the Europe has been working on development of a novel technology that could be used in homes of seniors. The main goals of the project were as follows:

- ♡ Choosing appropriate sensors;
- ♡ Implementing them in the simulation room;
- ♡ Creating the network of interdependent sensors;
- ♡ Introducing the technology to nursing students and future healthcare workers;
 - ♡ Providing safe environment and independence for seniors in the future;
 - ♡ Designing of the packaging for the sensors;
 - ♡ Inventing corporate identity of the project.



@ProjectCareAndConnect

Figure 172: Final design of the poster - attention grabber

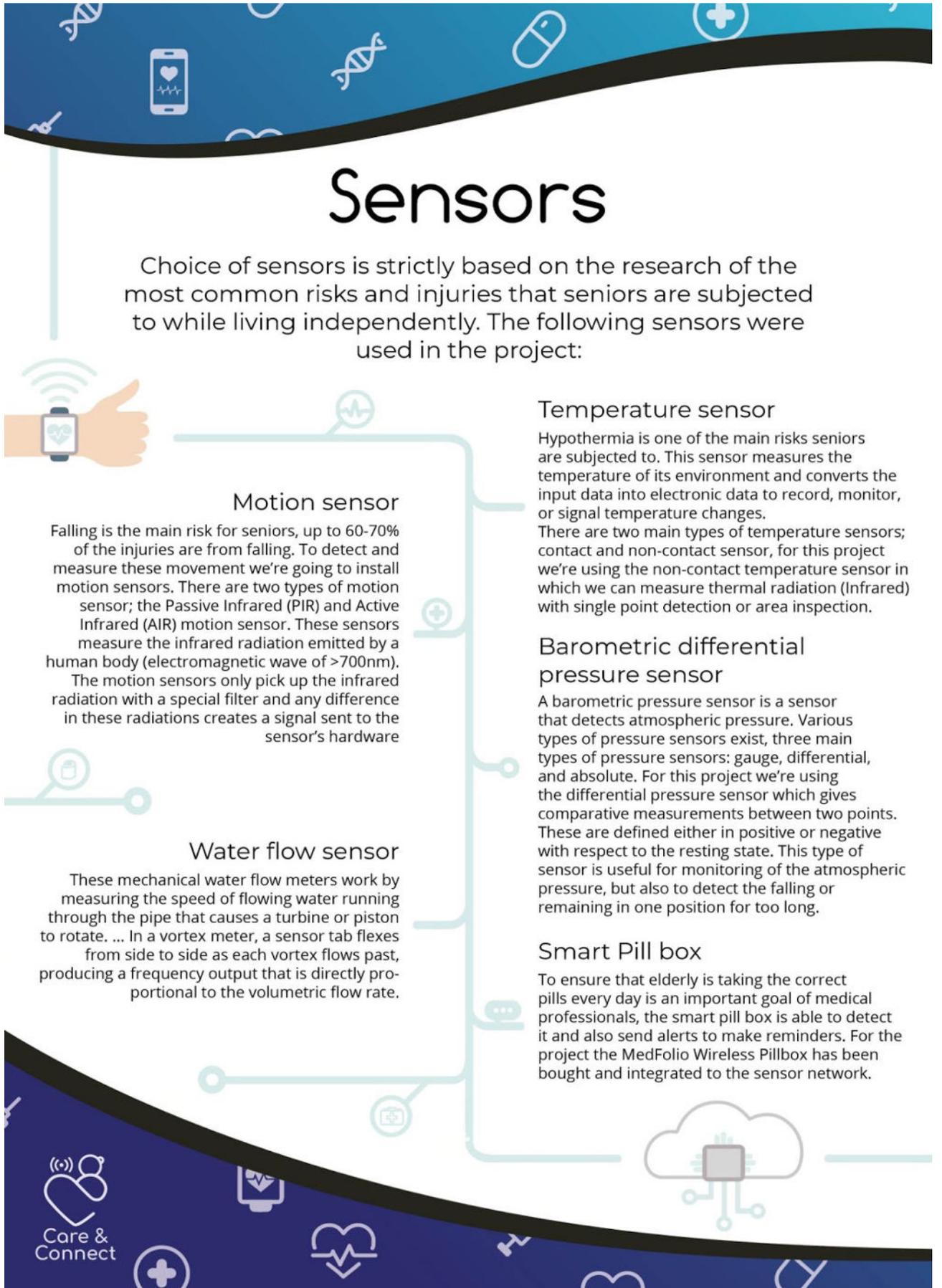


Figure 173: Final design of the poster – information (1)



CO and CO2 sensors

A carbon monoxide or carbon dioxide sensor is an instrument for the measurement of carbon monoxide and carbon dioxide gas. The most common principles for CO2 sensors are infrared gas sensors (NDIR) and chemical gas sensors. Measuring carbon dioxide is important in monitoring indoor air quality, while CO is a colourless, tasteless and odourless gas produced by incomplete combustion of carbon-containing materials and is often referred to as the 'silent killer'.

Pressure sensor

Falling during the night can be one of the most dangerous risks elderly may have, for this reason, pressure sensors on the bed and armchair to detect if there is someone or not during the night is a good solution. The working principal of the pressure sensor used is based on the piezoresistive effect that generates an electrical charge proportional to the applied force.

Humidity sensor

Humidity is a factor that hugely influences the physical well-being in the longer term - both high and low humidity have negative effect on your health. There are two main types of humidity sensors; relative humidity (RH) sensors and absolute humidity (AH) sensors. For this project we're using a DHT22 relative humidity sensor, this sensor works by detecting changes that alters the electrical current or temperature changes in the air.

Weight sensor

Nutritional problems can cause several complications in the immune system, in the energy levels or chronic health. For this reason, it is important elderly does not make big changes in their weight. In this project a sensor is used to detect and plot the weight in order to see if there are large variations. The sensor used consists of four strain gauges of 50 kg each connected by a Wheatstone bridge.

Door sensor

A door sensor is a device that can be attached into any type of door to detect if it is open or close, it works based on a magnet. When the door is closed, the two components are in contact and the circuit is closed. This kind of sensor can be useful for different things, such as detecting the door fridge, window doors or to detect the movement of the seniors around the house. In this project it is used to detect if they forgot the main door open or they are living the house in an anomaly time usually caused by dementia.



Figure 174: Final design of the poster - information (2)

10.7 Infographic

Nowadays, people are over-burden with data. This basically implies that getting your message out there requires something beyond plain content or pictures. In the last 3 years, infographics have arisen as a novel answer for keeping data short and presenting it in an engaging manner.

There is a quote that is quite common in the design world "words usually can't do a picture justice", since infographics have both 'pictures' and 'words', it addresses the smartest possible solution: the capacity to analyse a perplexing subject, and the capacity to attention of the user at the same time.

To make a great infographic you need to gather applicable information, compose convincing content, and present them in a productive and outwardly satisfying manner. By doing this, you can make even the hardest topic enjoyable and most importantly understandable.

Especially if you consider that the consumer only sees 20% of the content on a website page during a visit. Infographics permit readers to sweep or skim the information immediately, at that point choose if they need to discover more.

Infographic for Care & Connect.

The infographic is divided in 4 rooms being the kitchen, bathroom, living room and bedroom. This is done in such a way to make the reader understand that this can be implemented in any house or room. Further on the icons and information is divided over three groups: data resourcing, interactive objects, and responsive objects. This makes it easier to understand what each icon means but also easier to find specific information.

Almost every sensor has his own icon, but some share the same, this because they are the same sensor used in a different way. The information is all pushed to the sides of the infographic to create a certain peace of mind but mostly to make it easy to read.

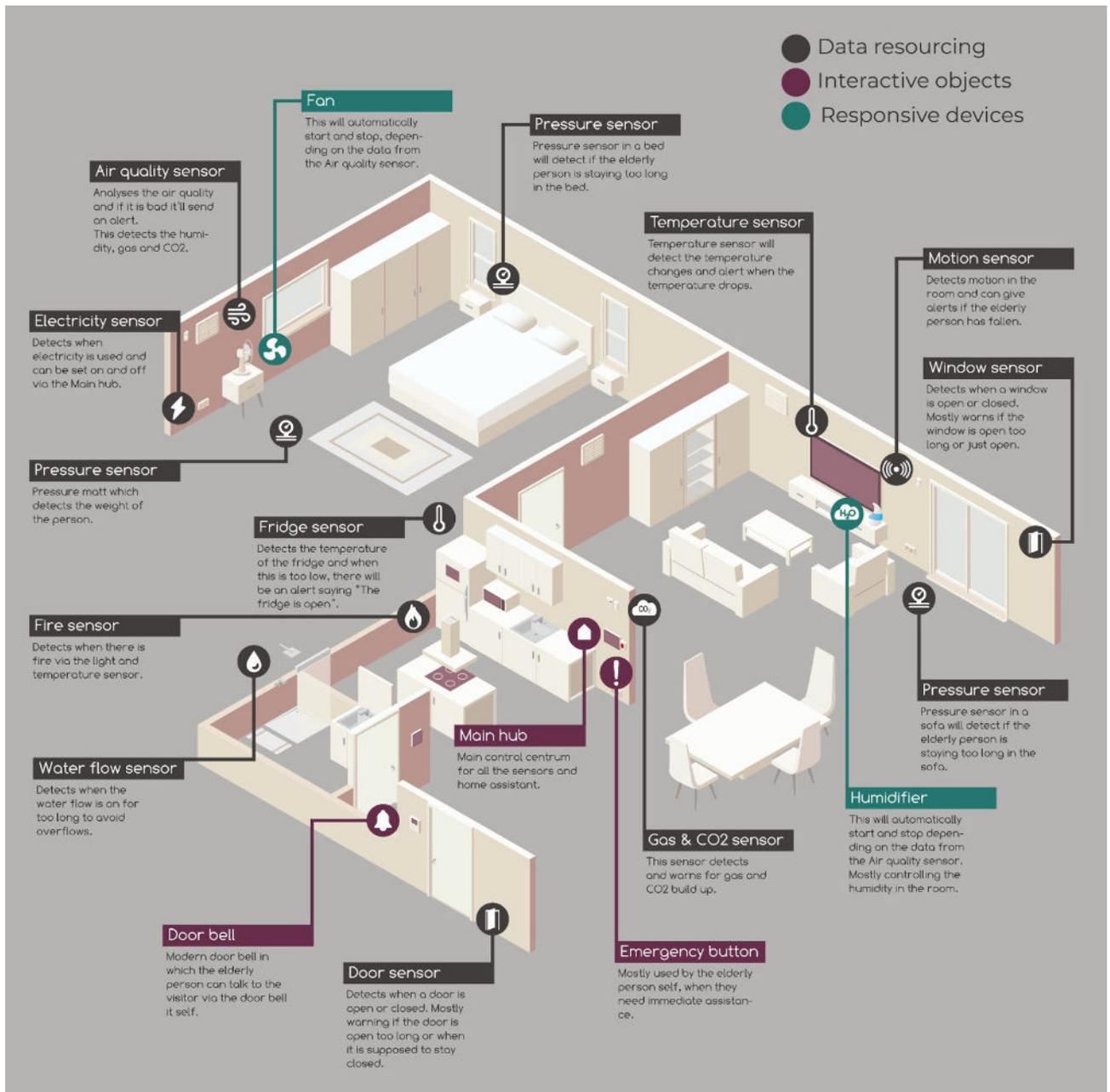


Figure 175: Final product of the infographic

10.8 Website

Once all this is taken into consideration, it is possible to take care of the website. To create it, it is important to think about an important element: with age, eyesight decreases, and it is more and more difficult for elderly people to read everything. It is therefore necessary to think about simple and accessible writing.

Nowadays, there are about 285 million blind and visually impaired people in the world. It is possible to categorize visual impairments into three different categories:

- Moderate impairment
- Severe impairment
- Blindness

These visual alterations lead to complications in being able to read, difficulties in being aware of spaces and therefore in evaluating one's movements. A person with reduced vision will have difficulty concentrating on a text for a long time.

Colour contrast is also the main point we have to take into account. The more contrast there is, the easier it is for a person to read, and even more so if they are a senior citizen or a person with visual impairments. The font used has to be the easiest and clearest one: we have to go straight to the information with as few embellishments as possible.

With these ideas in the back of our head, the start of the website really began. The website is divided in multiple pages being: Home, About, Sensors, Advantage, and Contact. With a subdiverging in About to the team.

The original plan was to create a website on which you can see all the data from the room in a front and back end which can be accessed by the nurses and elderly people respectively. In this idea we created a Wordpress website which could consolidate to our requirements. In the process of creating the website itself we came across a lot of problems due to the fact that the Wordpress website is fully set up on the Novia network and this network is quite heavily protected for in and outgoing information.

In other words, problem number one; you can't access the website outside of the Novia network (only with edu.roam or W33), problem two; the possibility to make the website connect to third party companies which support the software we need to make the wordpress connect to the mqtt or raspberry are not accessible, which leads to problem number three; no connection between raspberry or mqtt leads to the fact that the website can't be used as main hub for this project.

This is why the website is an information support then a main hub to read all the data of the sensors.

In order to make our communication proactive, we have chosen to communicate using several methods. The first one being social networks allowing us to reach a larger public but also to reach people who are not necessarily concerned by the subject and who consult the pages by simple curiosity. Then, key chains were printed so that students in nursing school could advertise the project themselves by having goodies attached to their keys.

Finally, we have set up a more permanent communication with posters that contain explanations on the different sensors, what they can bring and how to help nurses and elderly people in their daily life but also a provision of flyers to be able to take information at home.

The overall importance of healthcare software solutions is difficult to overestimate as technology promises to make healthcare services more effective and alleviate the burden placed on healthcare providers. This is critical in the context of the aging population and the increase in the number of chronic diseases.

The main advantages of IoT implementation in healthcare:

1. **Remote monitoring:** Real-time remote monitoring via connected IoT devices, such as sensors, and smart alerts can diagnose illnesses, treat diseases and save lives in case of a medical emergency.
2. **Prevention:** Smart sensors analyze health conditions, lifestyle choices and the environment and recommend preventative measures, which will reduce the occurrence of diseases and acute states.
3. **Reduction of healthcare costs:** IoT reduces costly visits to doctors and hospital admissions and makes testing more affordable.
4. **Medical data accessibility:** Accessibility of electronic medical records allow patients to receive quality care and help healthcare providers make the right medical decisions and prevent complications.
5. **Improved treatment management:** IoT devices help track the administration of drugs and the response to the treatment and reduce medical error.
6. **Improved healthcare management:** Using IoT devices, healthcare authorities can get valuable information about equipment and staff effectiveness and use it to suggest innovations.
7. **Research:** Since IoT devices are able to collect and analyze a massive amount of data, they have a high potential for medical research purposes.



filler picture

Figure 176: Picture of the Advantages page

Figure 177: Page for the MQTT-database



Figure 179: Mobile representation of the About page

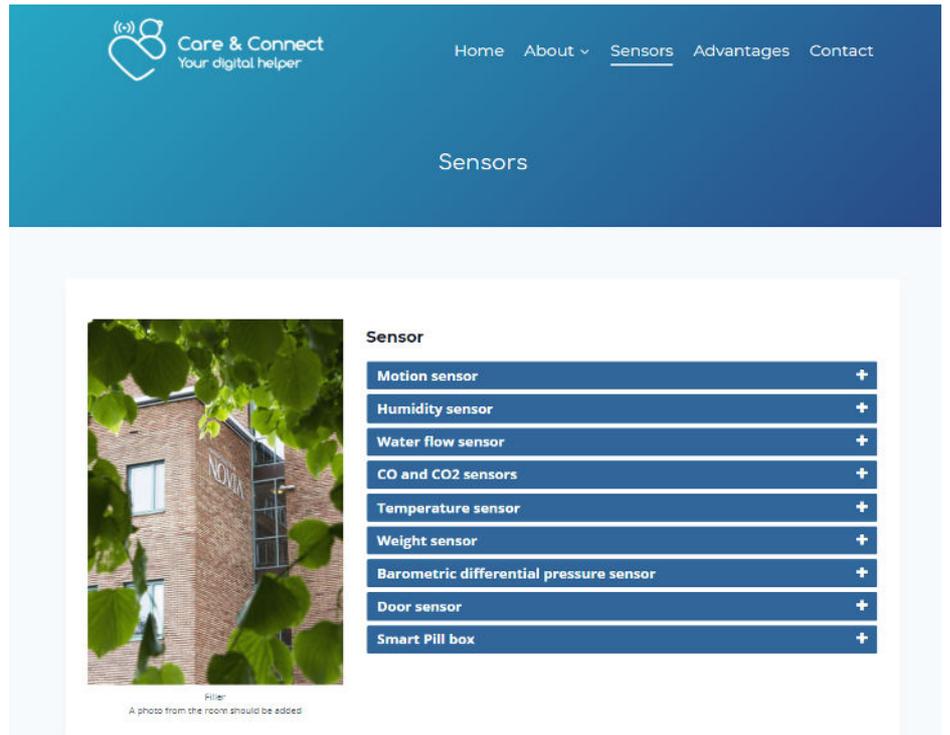


Figure 178: Page for the sensors with a foldable hamburger menu so you are not overwhelmed by all the information

11. Conclusion, discussion and suggestions

11.1 Conclusion

The given task from the beginning of the EPS was reached partially. We were given the task to create a network of sensors and educate people about the benefits of sensors. The educational mission is marked as completed because we have a website in addition to information in the room such as flyers, posters and QR codes. There, interested people can inform themselves about our undertaking and read up on it. The task of creating a network of sensors and installing them in the simulation room was only partially successful. We have created a system on a Raspberry Pi, which runs a software that allows the sensors to connect. In addition, the collected data can be processed on the same platform and forwarded to other systems such as Philips Hue and Smart Plugs. In general, the system works very well, but not in the simulation room since the internet connection doesn't allow us to connect to each device.

There are a few reasons why that last part only succeeded partially. First of all, we were lacking time and experience in the field of programming and electrical components. Most of us didn't program that intense and not without any guidance. Programming Node-RED could only be started at a late stage in the project, as we were learning how to program thanks to the IOT course alongside our project. There we learned the basic building blocks of Node-RED and how to use it. Without this information, it would have been very difficult to set up the system and get along there. The learning curve was very steep and continuous.

11.2 Recommendations and suggestions

The general idea of creating a network of sensors, connecting them with the internet and then analysing the gathered data is realizable. The biggest problems we had were with the connection in the W33-STUD network. The WIFI network in the Alere building was only partially accessible and caused problems for us connecting our devices with it. The Home Assistant and sensors were able to connect and exchange data within the network, but we had problems with external devices like the smart sockets and Philips Hue. These accessories needed to be connected via LAN or WIFI to the network, which is problematic since the network is hardly restricted. The smart plugs work in general with any network but won't connect to the W33-STUD WIFI. The Philips Hue Bridge, Lamps and Switches can't be controlled, since the simulation room in Alere has no accessible LAN socket for our project.

We suggest creating a network with a separate router in the simulation room, which is only accessible for the Care&Connect devices. This allows you to customize your router settings according to your preferences. It would also solve the problem with the paid cloud. The Cloud costs \$5 per month and would not be necessary if we had access to these settings. Another benefit would be that we could use ESPHome as a plugin in the Home Assistant and create a graphical dashboard with all the sensors and elements.

One thing we have not managed to do is to develop an app that sends messages automatically when things happen and also is connected to all different sensors. For us it was an interesting thing to bring in, but under the circumstances it was too much work to develop it. The app should be accessible to the caretaker, family and if needed other person groups.

If the problem of a closed network could be resolved and the possibility is there to use the website as a main hub, then there are solutions to make it work via a plugin of WordPress, via downloading external files which can connect the node-red to the website or to connect the website to the Home Assistant.

First one being the WordPress plugin: <https://wordpress.org/plugins/ecava-diot-scada/>
The DIOT SCADA with MQTT has a two-way connection from broker to website and website to broker, it's a paid plugin but gives you great opportunities to create a nice design in the front end of the website. The other upside of this plugin is that it can communicate with other plugins of WordPress which makes it easier to put it in a theme or other layout you like.

Next up is the external file: <https://github.com/Automattic/node-red-wordpress>. Once these files are uploaded to the WordPress as a plugin it can connect to the node-red via an easy way. Big downside to this one is that it is a bit trickier since these are outside files in the beta version, and they might give problems which haven't occurred before for someone else. So, it will be fully up to yourself to fix it. It does sound like one of the best ways to make the website work, but it also has the highest risk of breaking the whole project.

And finally, it's the connection with the Home Assistant: <https://www.home-assistant.io/integrations/rest/>. This is a connection between the website and Home Assistant. Again, this one is paid but has a lot of potential to create a nice design or layout. It has the same way of thinking as the Home Assistant and once the connection is made it should be plug and play.

12. Appendices

12.1 Belbin test

Dr Meredith Belbin discovered with his team that there are nine different clusters of behaviors and each of them represents a team role in a group. To have a good team which performs well together you will need all different team roles but also know who has which role in order to adapt the group work to each character and be as efficient as possible. It is not essential that all roles are represented by one person each. Most people have two or three team roles which pierce out. These team roles will change over the years with the experience and projects. Our professor Roger, in project management, told us that in the beginning of work life most people will have a lot of different team roles and their Belbin test will be more balanced. When they have done some project work and experienced the working life their Belbin test result will change in one specific direction. Each team role Belbin mentions is equally important and has its strengths and weaknesses. It is therefore important at the beginning of a group project to know which team member has which team role¹⁹⁷.

12.1.1 Team roles

Resource Investigator	With their inquisitive nature, they are able to constantly bring new ideas back to their team
Teamworker	Is the connection between the team to work together smoothly, while using their skills to identify the required work and completing it together with team
Coordinator	Divides and delegates work to achieve objectives more quickly and easily
Plant	Solves problems in unconventional ways through creativity
Monitor	A logical thinker, he/she will make impartial choices by constantly evaluating all the options presented to him/her
Implementer	Implements strategies to move in the right direction
Shaper	Allows the team to stay focused and always on track to evolve more efficiently
Finisher	Very efficient on all deadlines, end of tasks he/she has the role of fine tuning and identifying all remaining errors

Figure 180: Different roles given by the Belbin Test¹⁹⁸

¹⁹⁷ <https://www.belbin.com/resources/free-belbin-test-looking-for-a-free-team-roles-test/>

¹⁹⁸ <https://www.belbin.com/about/belbin-team-roles/>

Our Team roles

In our project group we have a lot of different team roles present. Most of us are team workers which will help provide a good base for the atmosphere and balance in the team. In general, we have almost every Belbin team role covered. However, the results of the test say that we are not as strong in the Monitor and Plant roles. These two roles work together, as they complete each other. When one is able to propose many solutions, the other is able to define the best ones. On one hand, the lack of Plant means that we might have difficulties coming up with alternatives or good ideas. On the other hand, absence of the Monitor role will be about the difficulties we will encounter; we might have difficulties evaluating them.

The lack of those two points has been already observed for example when we had to find a name. Because of our "scientific" way of thinking and seeing things we had difficulties to be creative to find the right name. Then, during the different proposals we had difficulty in realizing which one was the most appropriate.

But after working for almost 2 months together we do not see any disadvantages and are confident that our team is well-balanced.

Below there is a diagram with all our results.

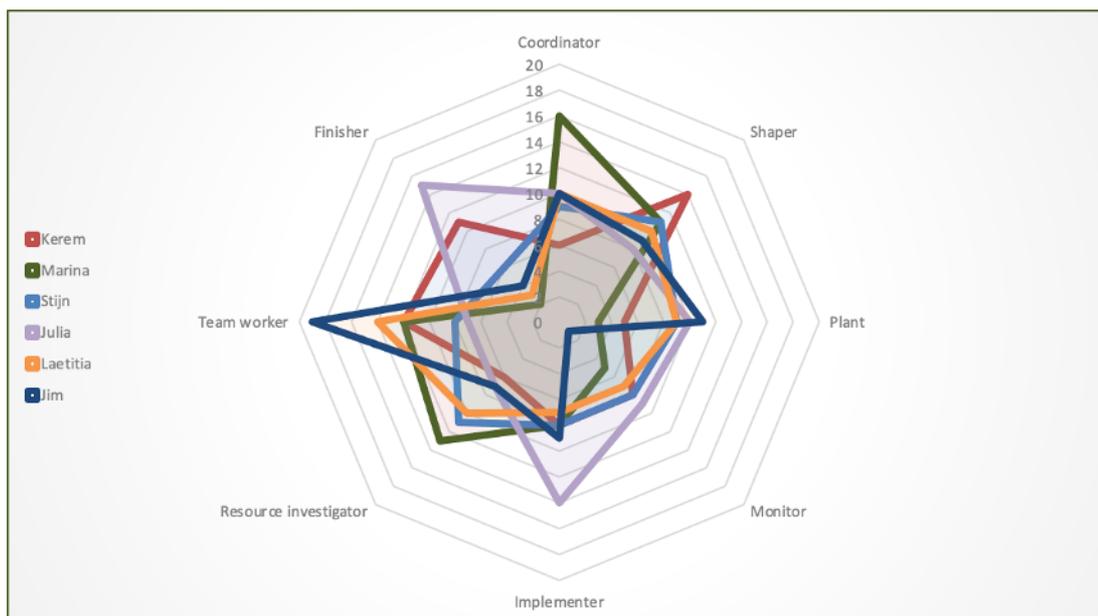


Figure 181: Graph representing the results of the whole group

In the following you can see each team member's individual Belbin result with a few strengths and weaknesses for each role that the person has.

Stijn Peeters

This was the first time that I did a Belbin test. At my home school we used another method to do a self-evaluation, with that method I had the result that I am a go-getter and a convincer. If I look at my results, then I almost agree with everything. One of the weaknesses of a coordinator is “might offload their own share of the work”, this doesn't match with my personality. I would rather take over someone else's job, that way I can be sure that it is done properly. When I look at the other results of the test I agree with them, they match pretty well with my personality. I am always enthusiastic when I get a new task that's a real challenge. The bad part of this is that I am sometimes overoptimistic, and I take on too many tasks. I am also a social person; I like to get to know new people and expand my contacts. When there is a lot of pressure I work harder because I want every team member to be proud of me. Also, dynamic is a part of my character, I don't mind that I need to break my daily routine to work on something. The one thing I learned in my life is that you always need to believe in yourself. That is the reason why I am confident.

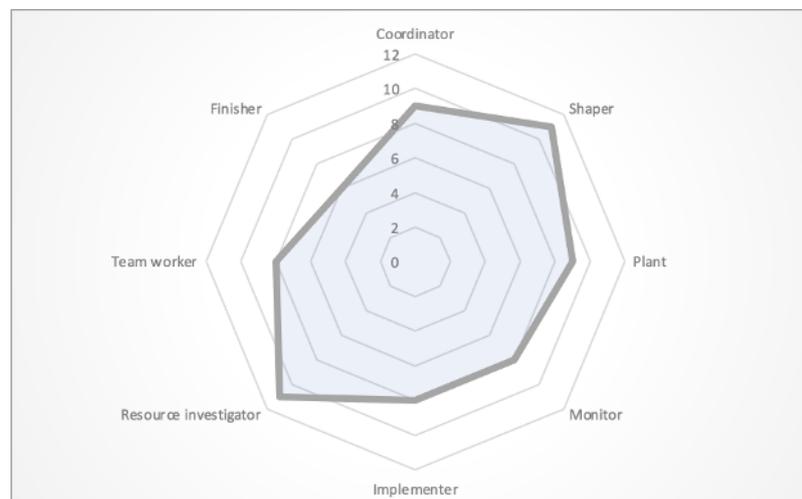


Figure 182: Graph representing Stijn's results

Strengths	Weaknesses
<p>Resource investigator: Extrovert, passionate, explores and creates contacts</p> <p>Shaper: Always challenging, energetic, likes to work under pressure</p> <p>Coordinator: Mature, confident, identifies talent, clarifies goals</p>	<p>Resource investigator: Can lose interest easily once the enthusiasm has passed</p> <p>Shaper: Provocation Offend people's feelings</p> <p>Coordinator: Can sometimes delegate too much and delegate its own work</p>

Figure 183: Table of strengths and weaknesses (1)

Jim Van den Troost

In my college we already had some tests to find out what kind of person you are, one of these tests was 16 personalities and me. From there on out we found out which strengths and weaknesses you have but also what kind of member you would be in a group project. And these results have been tested a lot for me because most of my projects are done in a group and most of the time, I was either the leader or the person who kept the group together, so everything flows easily.

For the Belbin test itself I was sure that I was going to be a Team worker first but I'm a bit surprised with the plant and coordinator as second and third. But after I read the explanation, I can see myself in them, especially in the plant since I'm a creative mind which likes to explore the unknown and unventured ideas.

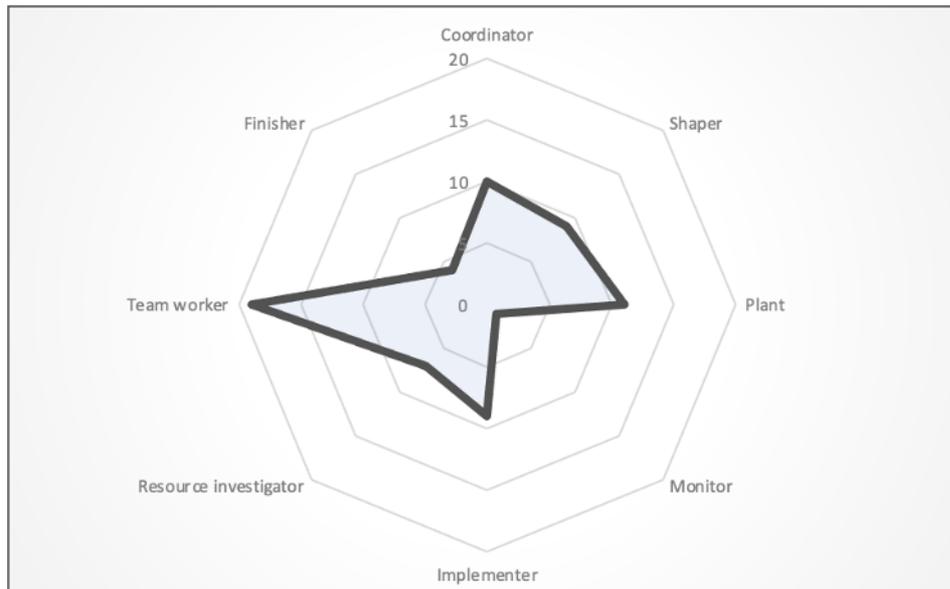


Figure 184: Graph representing Jim's results

Strengths	Weaknesses
<p>Team worker: Co-operative, perceptive and diplomatic listens and averts friction</p> <p>Plant: Creative, imaginative, free-thinking, generates ideas and solves difficult problems</p> <p>Coordinator: Mature, confident, identifies talent, clarifies goals</p>	<p>Team worker: Avoiding confrontation Indecisive in crunch situations</p> <p>Plant: might ignore incidentals Too preoccupied to communicate</p> <p>Coordinator: can sometimes delegate too much and delegate its own work</p>

Figure 185: Table of strengths and weaknesses (2)

Julia Nowakowska

It was the first time I had ever taken the Belbin test. Unfortunately, at my home university. I have never encountered this method of self-evaluation. I got to know a little bit about different team roles during a lecture from Project Management. Before taking the test, I was expecting to get the 'finisher' result as the primary one. And my intuition did not disappoint me in these predictions. Having participated already in many projects at my university, I discovered that I am very task oriented and I want very good results from the project. I am also very dedicated to finishing every task before the deadline. I also tend to think that everything should be done perfectly, which may interrupt sometimes in achieving a goal more quickly. I was surprised, however, to find out that my third role is a coordinator, because I have never perceived myself as a person with leadership features.

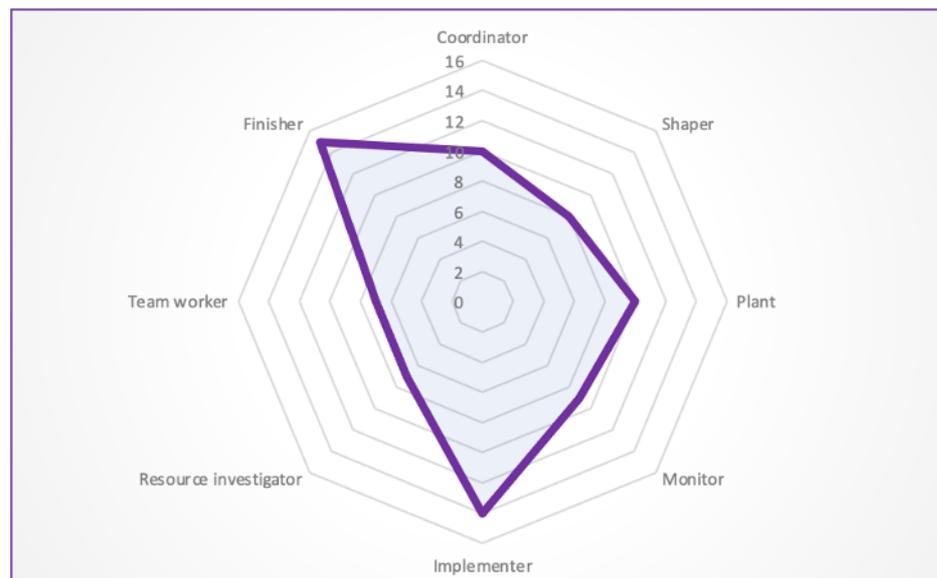


Figure 186: Graph representing Julia's results

Strengths	Weaknesses
<p>Finisher: Painstaking, conscientious, anxious, searches out errors, polishes and perfects</p> <p>Implementer Reliable and efficient person. When he/she speaks, he/she acts</p> <p>Coordinator: Mature, confident, identifies talent, clarifies goals</p>	<p>Finisher: Worry unduly, reluctant to delegate, extreme perfectionism</p> <p>Implementer: Most of the time inflexible</p> <p>Coordinator: can sometimes delegate too much and delegate its own work</p>

Figure 187: Table of strengths and weaknesses (3)

Ege Kerem Bektemur

In my previous project at my home university, we also took a Belbin test, so I am already used to working with this system. Before taking the Belbin test I had read all team roles and their different aspects, strengths and weaknesses. The results of the Belbin test are the same way I expected my roles according to Belbin. I always try to deliver the final result perfectly and according to the conditions. Therefore, it was clear that I was given the role of the finisher. I am also working very well under time pressure and try to push my team to get the most effectiveness out of everyone. The role as a team worker is something that comes naturally to me, because you always have to work together in a team and good harmony in the team promotes cooperation and therefore the project.

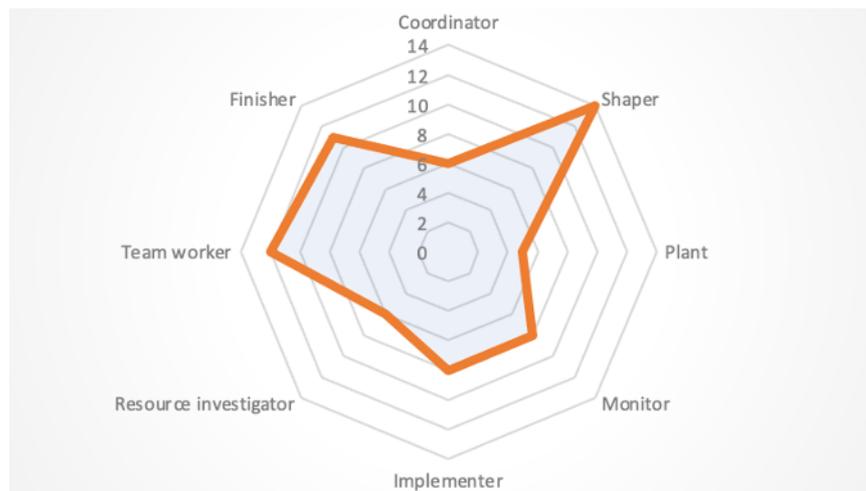


Figure 188: Graph representing Ege Kerem's results

Strengths	Weaknesses
<p>Team worker: Co-operative perceptive and diplomatic listens and averts friction</p> <p>Shaper: Always challenging, energetic, likes to work under pressure</p> <p>Finisher: Painstaking, conscientious, anxious, searches out errors, polishes and perfects</p>	<p>Team worker: Avoiding confrontation Indecisive in crunch situations</p> <p>Shaper: Provocation Offend people's feelings</p> <p>Finisher: Worry unduly reluctant to delegate extreme perfectionism</p>

Figure 189: Table of strengths and weaknesses (4)

Marina Duclos

I knew about personality tests, but I had never heard of the Belbin test. I like to think I'm pretty self-conscious and reflect a lot on myself and my personality. That's why I was expecting the coordinator role as my main one, and it didn't come as a surprise. I know I tend to take the lead sometimes and feel confident in dividing the work between my colleagues, considering each individual's strengths and abilities. I was also expecting the teamwork trait, as I am someone who needs a group dynamic to be able to work efficiently. I like to be surrounded by people I trust, and exchange ideas together. I believe the best way to be efficient and produce good work is by mixing everybody's abilities and knowledge. I would say the results suit me pretty well, as I identify with most of the strength it says I have. It also highlights my insecurities, which are all listed in the weakness. But it's a good thing, and I can now work on them.

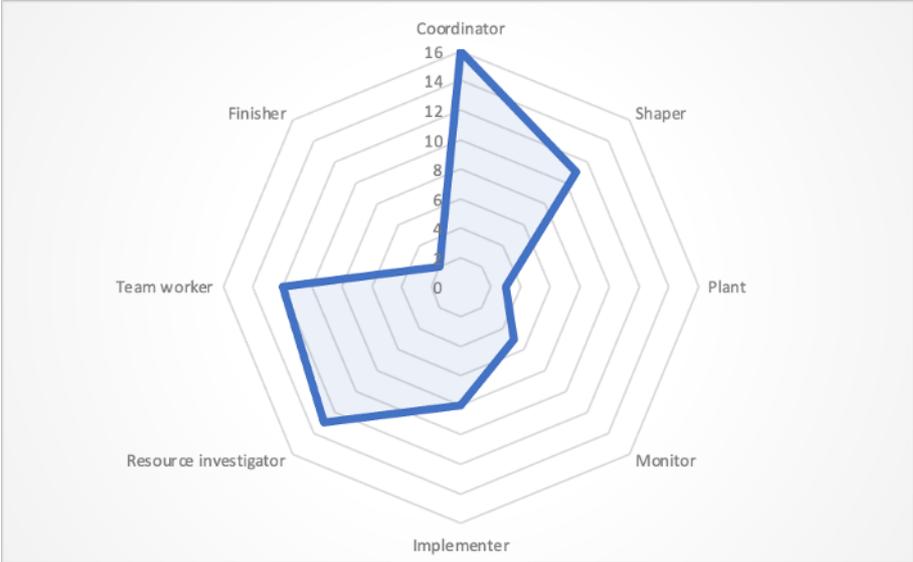


Figure 190: Graph representing Marina's results

Strengths	Weaknesses
<p>Coordinator: Mature, confident, identifies talent, clarifies goals</p> <p>Resource investigator: Extrovert, passionate, explores and creates contacts</p> <p>Team worker: Co-operative perceptive and diplomatic listens and averts friction</p>	<p>Coordinator: can sometimes delegate too much and delegate its own work</p> <p>Resource investigator: Can lose interest easily once the enthusiasm has passed</p> <p>Team worker: Avoiding confrontation Indecisive in crunch situations</p>

Figure 191: Table of strengths and weaknesses (5)

Laetitia Chopard

This is the very first time I have done a Belbin test. I had already taken other tests to determine my personality within a company and that is why I am not too surprised by the results. My main role is that of "Team worker" and I think it is the one that suits me best. I like to work on new projects with new people because you can learn a lot from others by sharing; even learn about yourself by learning to work with different personalities. Then at equal level I correspond to "Coordinator", "Shaper" and "Resource investigator". I think this corresponds to the fact that I like to divide the tasks between people properly, i.e. assigning them to the people who can contribute the most on certain tasks. I also like, when I can, to bring in people from outside the project to help us. This always brings an interesting expertise but also an outside point of view.

I am not surprised that I am not a Finisher (my lowest score). Indeed, I tend to like to start projects, find the ideas and see the evolution rather than seeing the finished work.

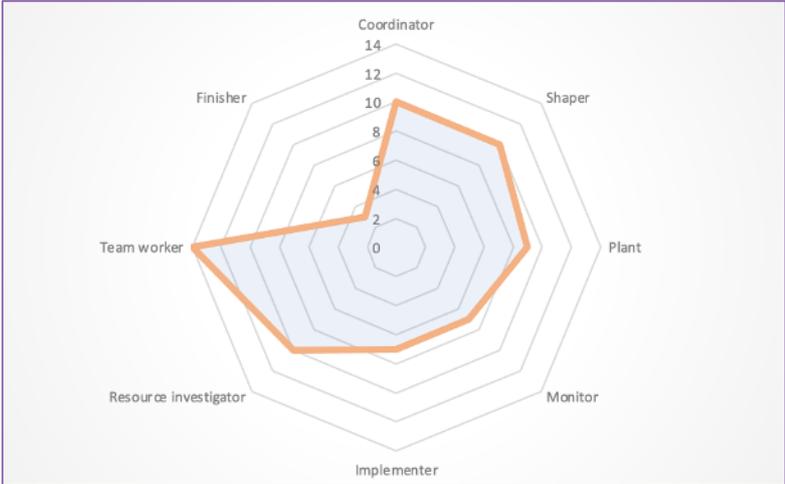


Figure 192: Graph representing Laetitia's results

Strengths	Weaknesses
<p>Coordinator: Mature, confident, identifies talent, clarifies goals</p> <p>Resource investigator: Extrovert, passionate, explores and creates contacts</p> <p>Team worker: Co-operative perceptive and diplomatic listens and averts friction</p>	<p>Coordinator: can sometimes delegate too much and delegate its own work</p> <p>Resource investigator: Can lose interest easily once the enthusiasm has passed</p> <p>Team worker: Avoiding confrontation Indecisive in crunch situations</p>

Figure 193: Table of strengths and weaknesses (6)

12.3 Work Breakdown Structure

The WBS is a tool that helps a project run smoothly. It allows to set up a structure of division of the project which makes it possible to define and simplify it. Indeed, it will be divided into groups of activities and will allow to define the tasks more easily afterwards.

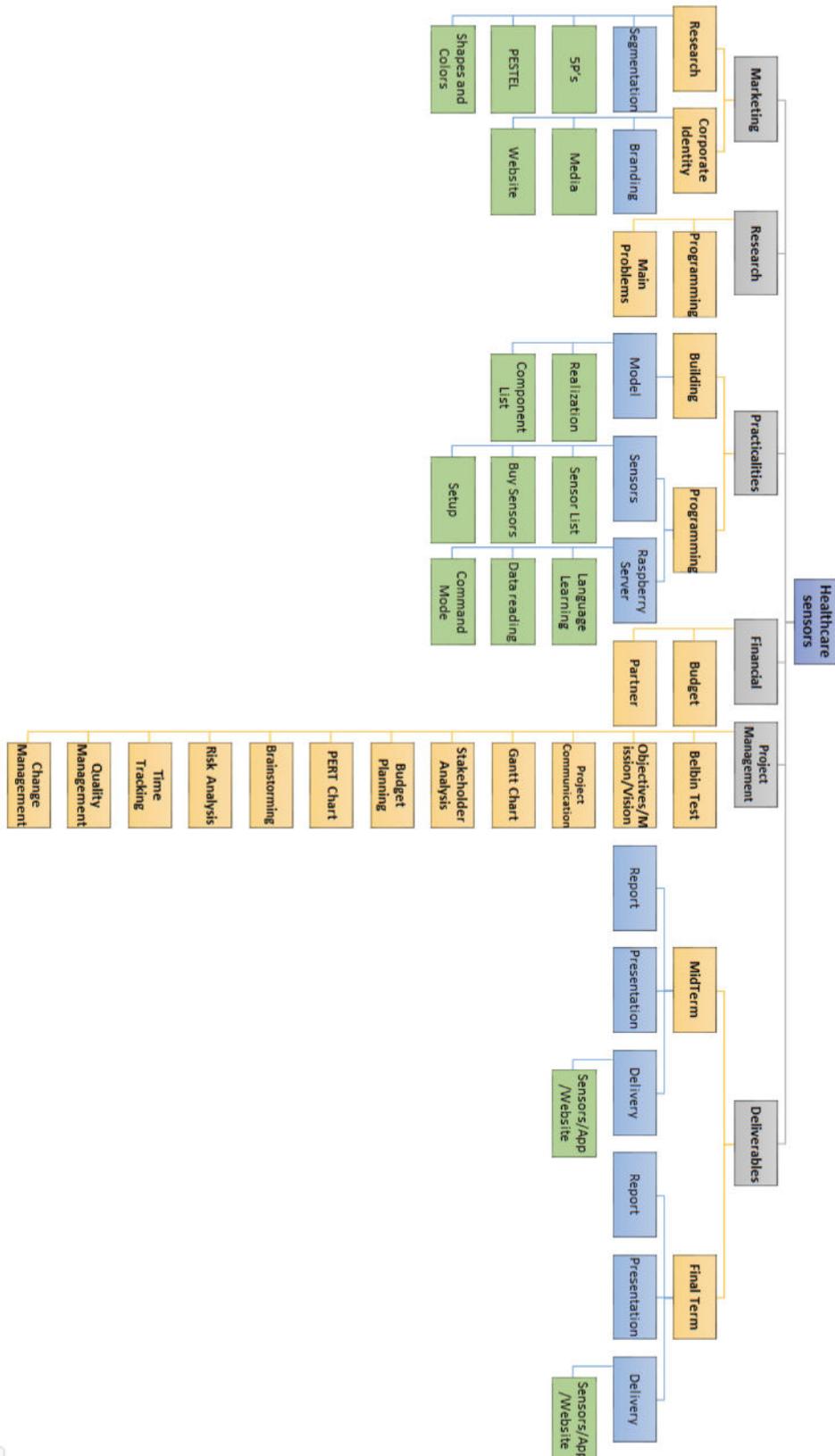


Figure 195: Graphic of the Work Breakdown Structure of the project

12.5 PERT

PERT (Program Evaluation and Review Technic) is a project management tool. It allows you to organize the different tasks in time. But be careful, it is more than a schedule because it highlights the critical tasks that cannot be delayed and shows the project under several options: when it finishes at the earliest and when it finishes at the latest. This allows you to have a good overview and to know if the project will be delivered on time.

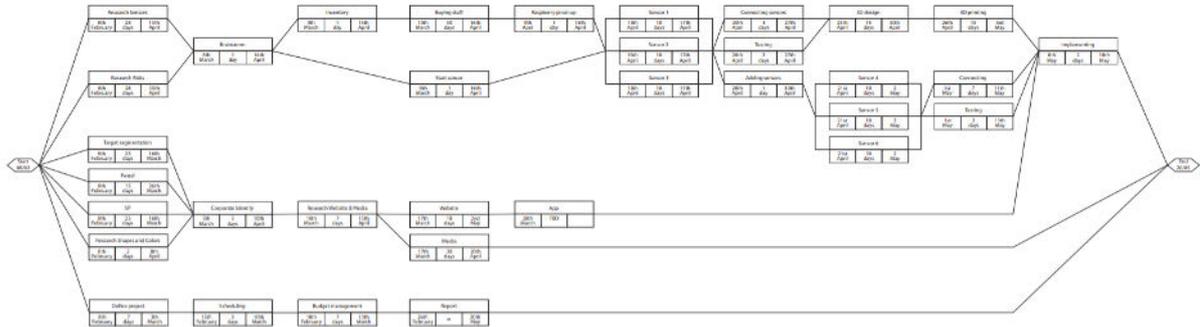


Figure 197: Illustration of the PERT of the project

You can access a more readable version with this QR code:



Figure 198: QR code for PERT

12.6 Stakeholder Analysis

The term stakeholder refers to a general term to describe individuals, groups, or organizations, who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of the project.

Stakeholder Matrix

1. Project group
2. Novia university
3. Supervisors
4. Hospitals
5. Healthcare workers
6. Elderly people
7. Government
8. Other companies
9. Cleaning staff
10. Family

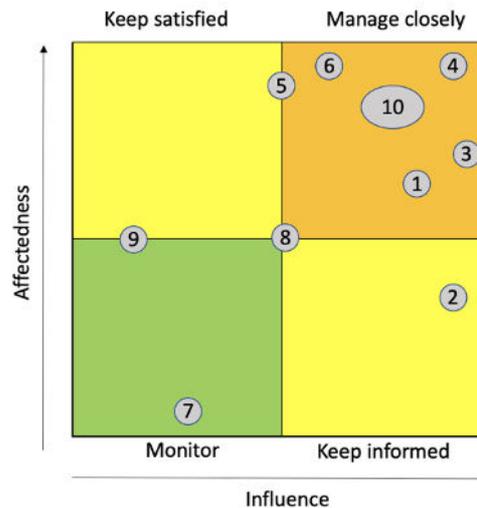


Figure 199: Illustration of our stakeholder analysis

Stakeholders²⁰¹

Project group

We are the persons who work on the project, therefore our actions and decisions affect the other stakeholders. We are actively influencing the outcome of the project. Our affectedness is high but only till a specific point because we aren't going to use the system we provide. We are only developing it.

Novia University of Applied Sciences

The Novia University of Applied Sciences is important because they are responsible for the simulation room and our general project. They also are giving us our budget and organizing extra classes to support our project.

Supervisors

Our supervisors are Mikael Ehres, Linda Jönn and Viveka Öling-Wärnå. They have a lot of power in our project, give us feedback, help us with difficult questions and set our course straight when we make mistakes. This stakeholder is directly next to our group because they have the same amount of affectedness but have way much more influence on us.

Hospitals

Those are with the greatest influence and concern. They have a great reach and would bring in big profits if ordered. They are also role models for other institutions, which would increase the publicity.

²⁰¹ <https://www.pmi.org/learning/library/stakeholder-analysis-pivotal-practice-projects-8905>

Healthcare workers

Healthcare workers are directly in touch with the system we are working on. Their opinion and criticism must be taken seriously, as the product is aimed for their daily use.

Seniors

Seniors are our main target group and should be watched out with extreme caution. The systems are optimized for their daily life and are designed for helping them.

Government

The government has a lot of power with laws and regulations. They are not affected in any way possible, rather than setting our general conditions with privacy law and DIN-norms.

Other companies

Every other company that produces and develops sensors in the same field as us is a competition.

Cleaning staff

Cleaning staff is also in touch with the systems since they are responsible for cleaning the room. Therefore, we must look out if there could be any potential problems. Also, an explanation of how not to damage or adjust them is necessary because of the daily work around them.

Families

Families who are buying the systems for their seniors are also in direct contact with the sensors and the software. Therefore, they have a high influence and affectedness on our project.

12.7 Time tracking hours

To keep track of how many hours each member worked on the project, we created an excel file, where everybody could fill up their own time of work and specify what they were working on. In the first part of the project we mainly worked on research, and group meetings, both with and without our supervisors. However, in the second part, after the midterm, we were fully focused on the practical tasks: setting up and programming of sensors, 3D printing, graphic design, etc.

At this point in the project, we have 1645 hours in total, with an average of 274 hours per person. If we consider the average wage of a project engineer working in Vaasa, Finland, which is about 20,30 € per hour (according to “Payscale”²⁰²), the project would have cost 33.393 € in personal costs.

		TOTAL	289,133
Day	What		Hours
8/2/2021	COVID-19 & security		0,5
	Welcome to Vaasa!		1,5
	Learn how to use Peppi/Tuudo		1
9/2/2021	Library Tritonia		0,75
	EPS Project Management		3
10/2/2021	Project presentations with tutors		1,5
	Welcome to Vaasa + city of Vaasa		1,5
11/2/2021	Team building		2
	Project Management		3
	ICT services		0,5
12/2/2021	Meeting with Katja Bonas		0,5
	Project Meeting with Mikeal, Viveka and Linda		2
13/2/2021			
14/2/2021			
15/2/2021	Project Management		2
	Project Meeting with Eva Barcelo		2
16/2/2021	Guest Lecture - ECO DESIGN		2,5
17/2/2021	My research on sensors		1
	Guest Lecture - ECO DESIGN		2,5
18/2/2021	My research on sensors		1,5
	Project Meeting		1
19/2/2021	Project Management		0,5
	Project Meeting with Viveka, Linda, and Hans		1
20/2/2021	My research on sensors / IoT / Raspberry		1,5
21/2/2021			
22/2/2021	My research on sensors / IoT / Raspberry		2
	Project Meeting		2
23/2/2021	Meeting with Linda in Technobothnia		2
24/2/2021	Project Management		1,5
25/2/2021	Project Meeting		2,5
26/2/2021	Project Meeting with Linda and Viveka		1,5

Figure 200: Extract of one of our member's time tracking hours

²⁰² <https://www.payscale.com/research/FI/Location=Vaasa/Salary>

12.8 Gantt chart

The Gantt is a project management tool. It indicates all the tasks to be done, their duration, their order of priority and which tasks they depend on. This allows you to create a timeline of the project's progress. It allows you to have a precise follow-up of the realization of the project and to know the tasks in progress, the past tasks and those to come.

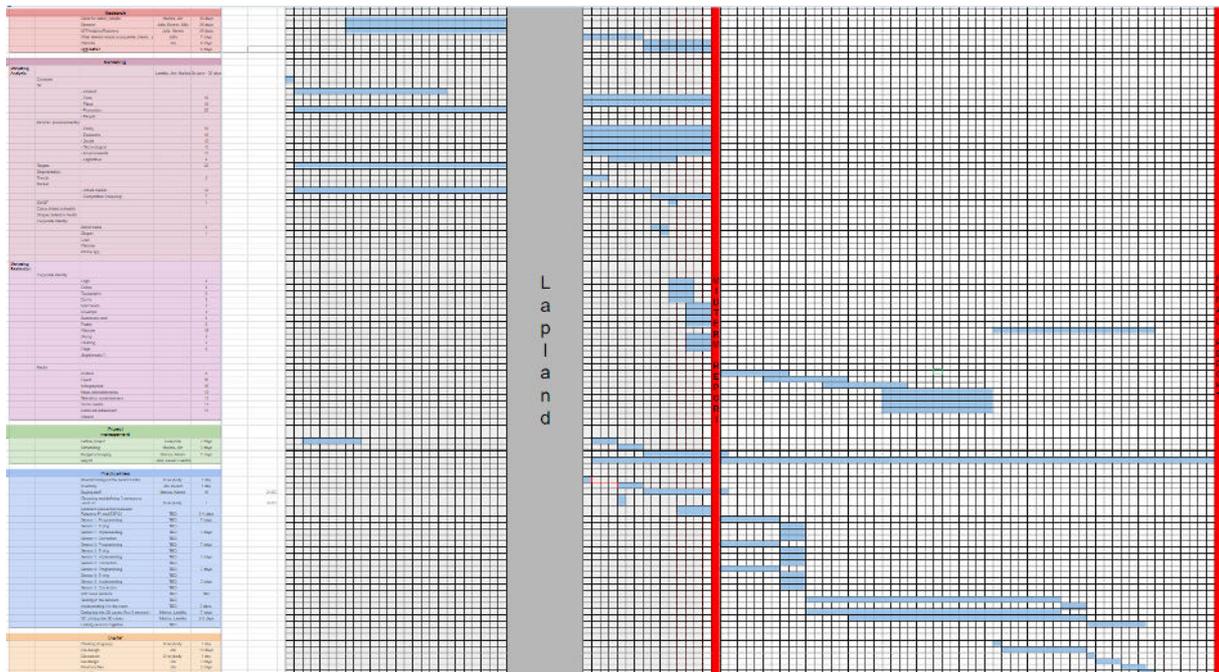


Figure 201: Overview of the Gantt chart

The Gantt evolved since we had two weeks more for our project. We also had an evolution because our delivery for the sensors didn't arrive on time. Due to that we reviewed our Gantt and set new times for ourselves.

You can access a more readable version with this QR code:



Figure 202: QR code for Gantt

The different project management tasks helped us to understand who the members of each group were, how they worked and what their faults and qualities were when working in a group. They also helped us to manage better our project by allowing us to understand better how to define our tasks, to distribute them in time but also to manage our budget. Finally, they also allowed us to highlight the risks that can be encountered during the evolution of the project in order to prepare and anticipate them.

12.9 3D-Simulation of the simulation room

The 3D image can help visualising the simulation room without ever being in there. It was created with a CAD software called Catia.

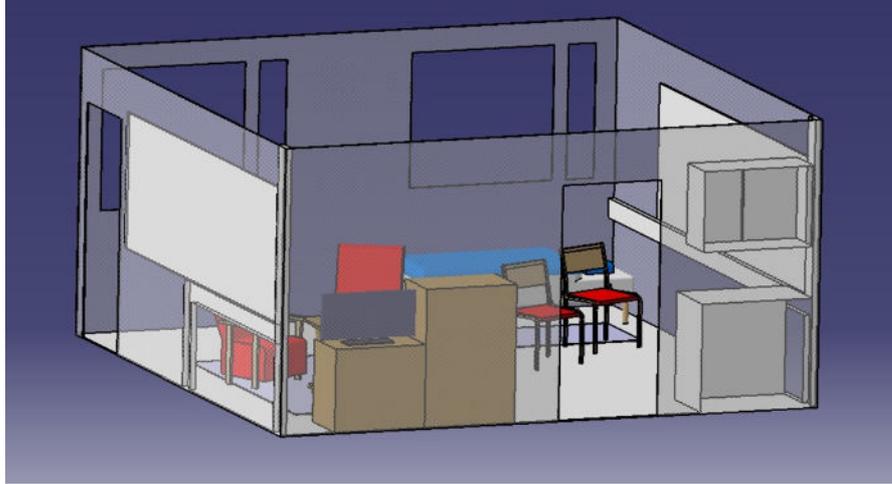


Figure 203: 3D image of the simulation room (1)

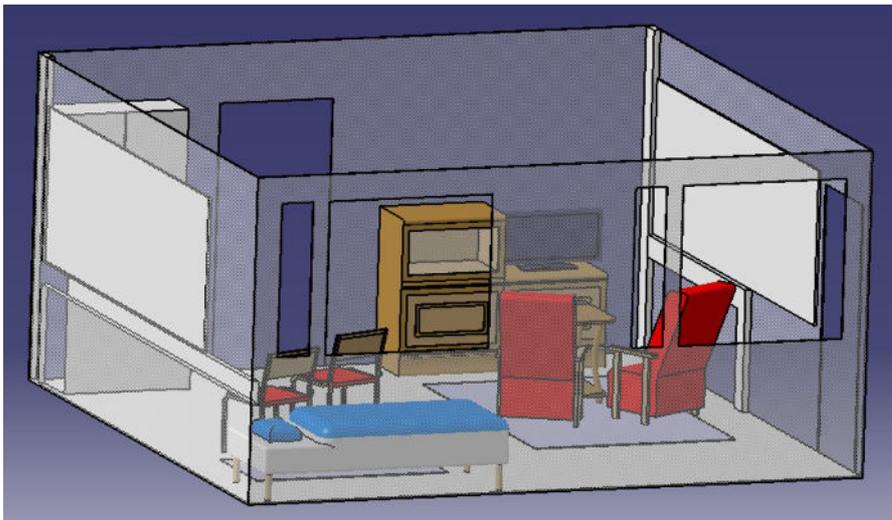


Figure 204: 3D image of the simulation room (2)

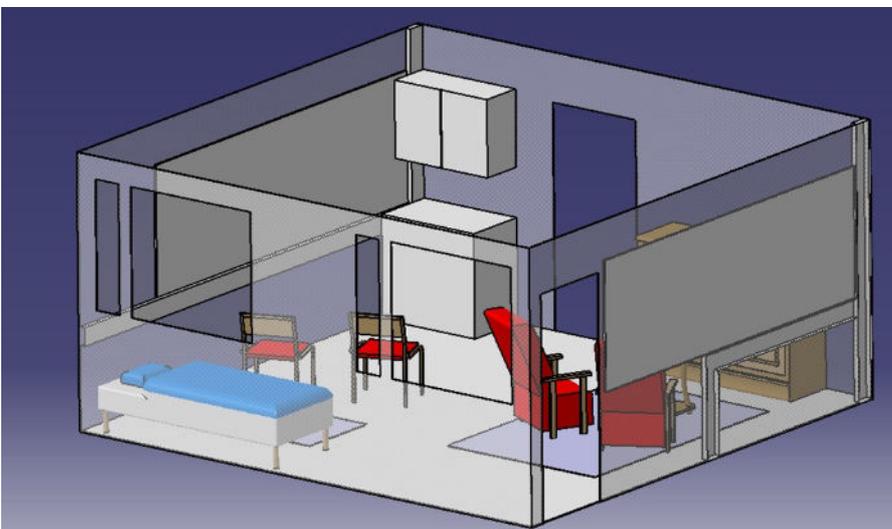


Figure 205: 3D image of the simulation room (3).

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