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ETSEIB

FINAL PROJECT:

THE LOCLOCK

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1 Introduction

For every human being the gradual reduction of physical and functional capabilities is an ineludible consequence. Despite this condition, the advanced age of people shouldn't be a hindrance for living an independent life without sacrificing herewith the security of people. The present project elaborated by five industrial engineering bachelor students aims to join on this problem and give a modest solution. Our personal challenge is to help the elderly living in nursing homes and give them an environment of greater autonomy and safety.

The present report has been written for a third-year-subject of an Industrial Engineering Bachelor's Degree. The subject concerned itself with developing specifically a technological solution for a problem. To this end a first part of the team-work has been to become acquainted with the Arduino environment. For this purpose the team has learned by doing the small projects contained in Arduino's Starter Kit. The progress and knowledge acquired was documented on a Wordpress blog [14]. The format of the Wordpress page was chosen to be informal, so that it could be of use to anybody with basic scientific background. The page is directed at young people with an interest to learn Arduino and it is intended to assist and encourage them to continue with their apprenticeship.

Before concerning ourselves with a challenge, the team considered different platforms to transfer the work's documents and to write down the finished work. To this purpose an organization page was chosen (which will be explained in the next section). To document and write the report, a member of the team learned its way through Latex and taught the rest of the group. Google Drive was also used to share papers and code files. GitHub has been used to share the code as it has a high length.

With all the required tools the team could fully focus on deciding upon a challenge to tackle.

1.1 Project Management

As a big project, it needs some organization in order to advance in the right direction. The whole project has been divided into smaller ones, and this sub-projects have been separated in specific tasks to do. The whole project has followed the same simple process for being designed, firstly we started with the initial challenge, which is to improve the life quality of people who lives in elder nursing homes. When the project's challenge was set, we started thinking in different possible solutions. The accorded solution was designed within the means we had available. After having a possible product, this was tested with users in order to get some feedback or critics in which we could base the changes and modifications of the *Loclock*.

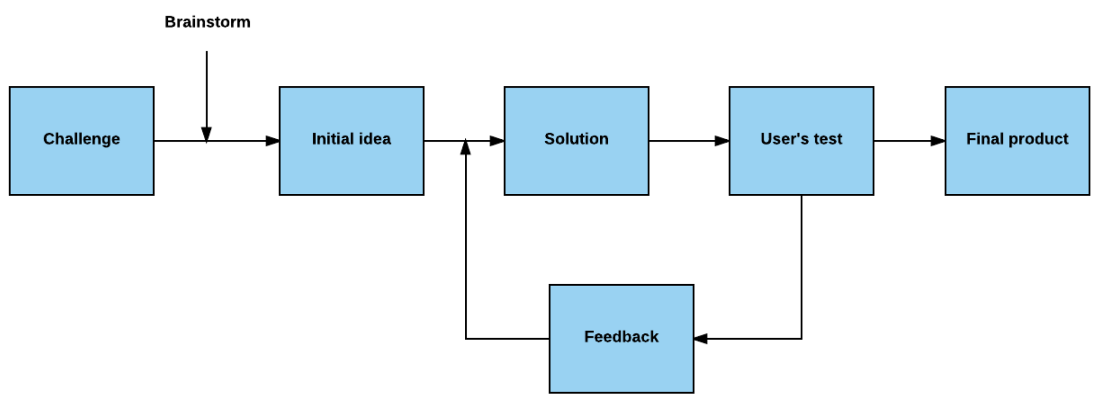

Figure 1: Project's flowchart

Each different task was designed to a component of a group in order to work in a specific part of the project.

The main parts of the *Loclock* are:

- Positioning module.
- Wireless transmission.
- Clock module.
- Alarm and sounds.

In order to schedule a timetable for our project and track the progress of the Loclock we used some online software. In our case the used software was Zoho Projects [15]. The page allowed us to write the tasks and meetings of each member and helped us keep track of the project's advances. It was an easy way to see every moment in what point of the project we were.

2 Design thinking [9] [5]

Considering the fact that the team had already defined a general challenge consisting in helping elder people in a nursing home, straightaway it was time to specify and optimize the manner to achieve it. The Design Thinking methodology, which first contemplates the general problem or necessity to solve and then leads to the final product was considered to be the best option.

The first step was empathizing with the chosen environment. The team contacted with the social assistant of a private nursing home in Sant Quirze del Vallès, Barcelona, and made an appointment with her. To get ready for the interview a brainstorming was made, where the questions to ask her in order to get information efficiently without influencing her answers were written down. The team also had the chance to talk to two persons living there and wrote down their opinion about the issue.

After understanding better their needs, the team gathered. Each member told real stories about elder people while the others wrote down all the ideas surrounding their minds. Afterwards, the ideas were clustered in order to have a clear structure of them and to facilitate deciding which ones where the most interesting for the project. As it is said, a picture is worth a thousand words:

Figure 2: Clustered ideas for the project (in Spanish and Catalan)

After all it was concluded that elder people have several problems owing to the lack of security. When they fall to the floor and can't reach the alarm button to contact the nurses; when they are scared, because it is possible they get lost if they go and walk in the street... There are many such situations. We also realized a discernment is needed to differentiate between people who need help because of a moving disability, and the ones who have a mental disability. The first ones need human help to take a shower, to dress up... while the second ones have a huge problem when they realize they are losing autonomy and it is not after this happens that they strongly need human help.

Considering all the collected ideas, it was decided that the project would be directed to people that don't have a moving impairment and also don't have an extremely developed mental disability. In other words, people who don't necessarily need human assistance. It was also decided that the project would be based on the security they wish to feel.

To understand better in which moment their sense of well-being was the lowest, a trajectory map was made to represent the sense of security they feel during the day, in order to see the critic moment; the best moment to act with the product.

Figure 3: Trajectory map

The final conclusion was that a technological device was needed to be able to lengthen people's autonomy while guaranteeing their safety. To achieve this the team decided to make a clock which warned the owner when he or she needed to have lunch, dinner, take a shower... A kind of alarm that memorizes all the things the person needs to do every day. Another function the clock would also have is an alarm button prepared to send the person's location to the nurses in case they got lost or they fall down, so they can get help rapidly.

3 The Solution

3.1 Introduction

The solution coming from the Design Thinking process will be now disclosed from a technological approach.

The transition between the ideas and the real project has been more difficult than it was expected.

The idea of elder-nurse connection has been applied with BlueTooth technology. The nurse can set or modify the alarms of the elder's watch from an Android mobile phone pressing buttons and writing commands in the Ardudroid app as it is explained in section 5 *User Manual*.

To know where the Loclock users are when an emergency appears there is a need of an indoor positioning system, which allows to rapidly find where the event is taking place. To get the location of someone in a room or floor, three distances from three different points are required. This is the starting point of the proposed system. It is based on three beacons, each one of them estimating a distance to the users. Every beacon emits radio frequency and ultrasound waves which attain the receptors being carried by the users. The position is then calculated by measuring the time delay between the arrivals of the two waves.

Note that at least three beacons are required in order to get a location in two dimensions. Nevertheless, more beacons would be needed to allow the proper functioning of the system on a nursing home. As it has been mentioned, ultrasound waves are required to travel from an emitter to a receiver. However, those waves could be perturbed by the topography (e.g. walls and windows) of the nursing home. To know the exact number of beacons the distribution of the nursing home should be studied.

There is always a beacon which acts as the master beacon sending out a synchronization message to all other slave beacons. The master acts first sending a radio frequency signal. Note that this kind of waves can transmit their identification number which gives information to the receptor to which beacon has to communicate [6]. After a known time since the RF signal has been sent, ultrasound waves are emitted. The last one travels at the sound speed (340 m/s), while the RF does at ultrasonic speed (it can be considered immediate). Therefore, there is a period of time for the receiver between getting the RF sign and the ultrasound waves. This time multiplied by the sound speed gives the distance between the beacon and the receiver.

As the purpose of this project is to demonstrate the viability of the proposed solution, the mechanism will be built employing a single pair of receiver and emitter. Consequently, the location of the target will be done on a one-dimensional geometry.

3.2 Wireless data transmission

First of all, it has been observed that one of the most important problems to solve is that the watch can't be connected with electric cables to the device used to transmit information to it. That's why different options like Wi-Fi, BlueTooth or Infrared rays have been considered.

BlueTooth Technology has been chosen because it has been found that it is not as difficult to implement as other alternatives. The shield used is named *HC-06* (full datasheet annexed) and it enables the Arduino UNO shield to communicate with an electronic device (if it can be connected to BlueTooth) by wireless connection. In this case, a mobile phone is used to transmit/receive data to/from the watch with an existing application called *Ardudroid* [16]. This "app" will help to display the received and transmitted data in an easy way (it will be useful for the indirect *Loclock* users, in this case, the nurses).

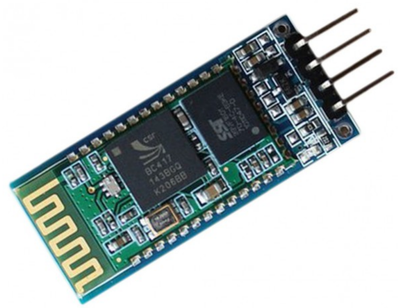

Figure 4: *HC-06* BlueTooth Module

3.2.1 Received data in *Ardudroid*

The indirect user will be able to get the actual localization of the watch or set alarms by clicking buttons (explained in section 5. User manual) in the *Ardudroid* application. In case of S.O.S alert, a message with the emergency time will be automatically received.

3.2.2 Transmitted data to the watch

The indirect user will have the possibility of modifying or deleting the set reminders whenever is wanted and of writing short text messages. It will be also possible to notify to the direct user that a nurse is coming in case of emergency.

3.3 Positioning module

3.3.1 Technical elements

This section contains the technical elements required to build the proper circuit in order to run the indoor positioning proposed above. As it has been previously clarified, the following explanations are referred to the one dimension assumption.

The radio frequency module which has been used is RF 433MHz Long Distance Transmitter/Receiver Pair, for the one dimension project only a pair is needed. It can be used as an Arduino module so that it does not require any external circuit. It is a long range 433 MHz radio frequency link kit which incorporates an encoder and decoder. Their pins are properly explained on the radio frequency tests section.

When building the indoor positioning circuit related to the ultrasound waves more components are required as any Arduino module cannot be used. The chosen ultrasound modules are 400ST160 40 KHz which can indistinctly work as transmitter or receiver (for our system two are required). In order to build the corresponding circuit to transmit and amplify the received ultrasound waves, the elements listed below are required.

Ultrasound Transducer		
Resistences	500 Ω	1
	1500 Ω	5
Transistors	2N3904	3
	2N3906	2

Table 1: Technical components required for the ultrasound transducer module

Ultrasound Receiver		
Resistences	330 Ω	1
	470 Ω	2
	4,7 kΩ	2
	18 kΩ	1
	22 kΩ	1
	47 kΩ	3
Capacitors	0,1 μF	3
	1 μF	1
Coil	33mH	1
Transistor	2N3904	1
Comparator	LM393	1

Table 2: Technical components required for the ultrasound receiver module

3.3.2 Electronic circuit

To drive the ultrasound emitter and receiver the electronic circuits shown below were built. As it was not within our knowledge's reach to design the electronic circuits and besides as it was far beyond the time and effort intended for this project, the schemes used were reproduced from a report [1]. However, the main working principle of the circuits will be explained.

The ultrasound emitter circuit scheme is sketched separately from the rest of the circuit. The ultrasound transducer is depicted in the scheme with a rectangle and it is located at the center, between the transistors. The aim of the circuit is to drive an AC voltage across the transducer. It works as follows: depending on the state of the digital pin attached to Arduino, the transistor-switches change positions and current flows across the transducer either right or left. This digital pin is controlled by PWM and thus the voltage drop across the transducer changes. The transducer is made of a piezoelectric ceramic material that oscillates at the same frequency as the AC voltage and produces in response an ultrasonic wave. The center frequency of the employed transducers is approximately at 40 kHz, beyond the human hearing scope, therefore the digital signal from Arduino should change at the same frequency [18] .

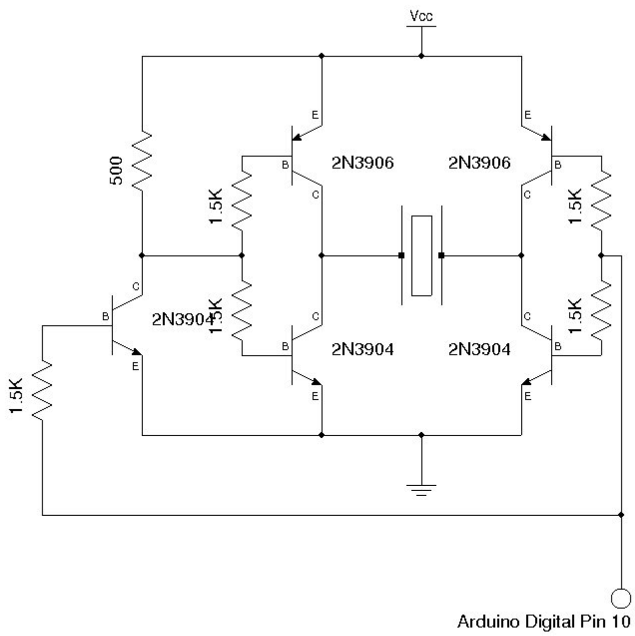

Figure 5: Ultrasonic emitter circuit shceme

The ultrasound receiver circuit is of a higher complexity than the transmitter one, as it does not only read and send the signal to Arduino. The circuit's design modifies the received signal and amplifies it.

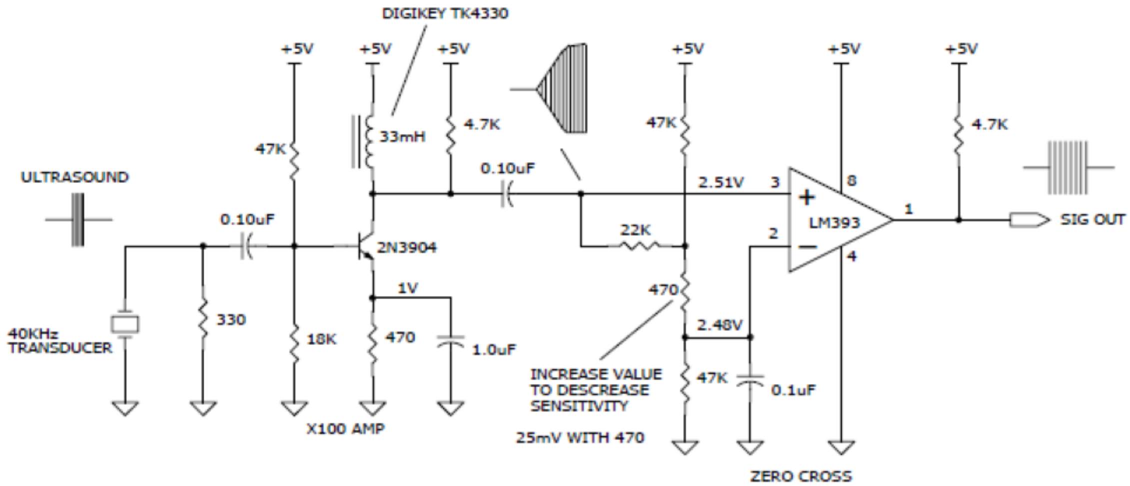

Figure 6: Ultrasonic receiver circuit scheme

The following images show the assembled system of the emitter beacon and receiver circuit including the RF module and the Arduino board. The ultrasound transmitter was positioned in another breadboard, because it was forewarned that the RF emitter module might interfere with the ultrasound waves. However, at our own experiments, this hasn't appeared to be the cause of interference. The radiofrequency signal is controlled by digital pin 8 of Arduino and the ultrasound circuit is attached to digital pin 10.

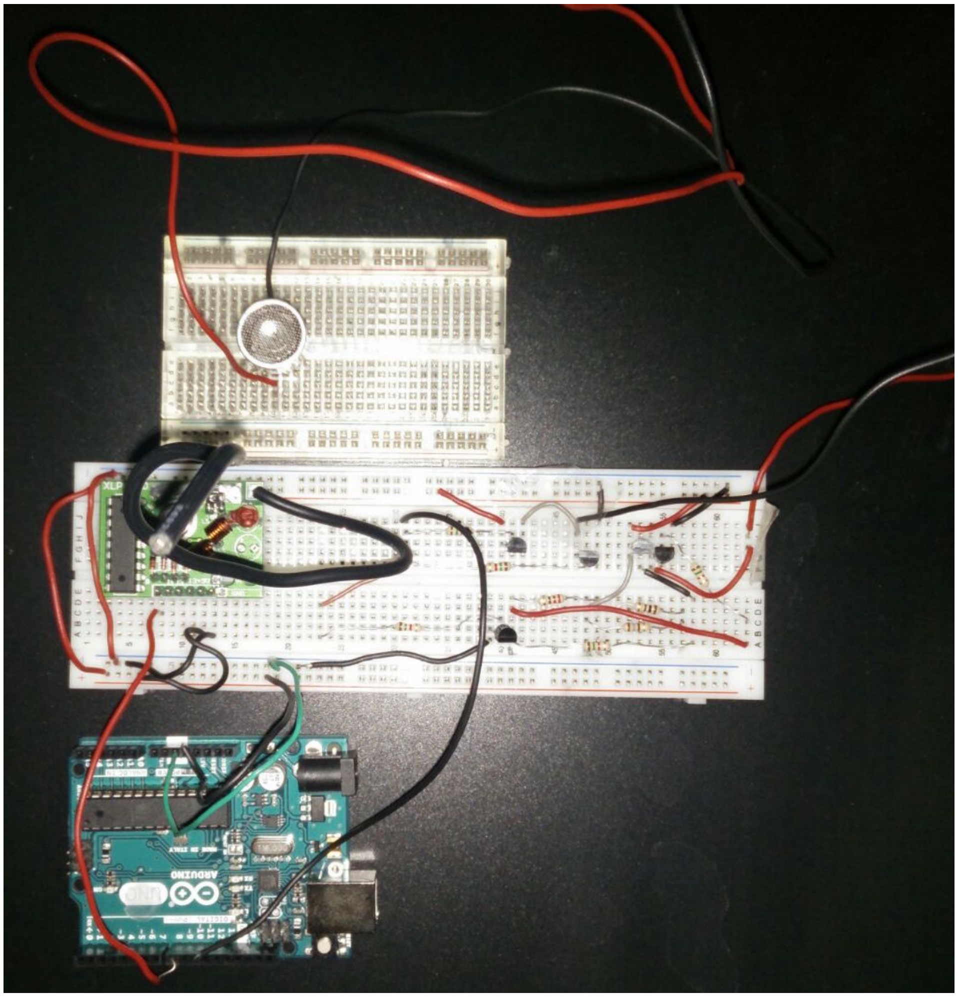

Figure 7: Assembled emitter circuit

At the receiver circuit, the amplified ultrasound signal is read through an analog input pin (A0) of Arduino. The RF signal is connected to the same digital channel as the RF emitter, which is D0. The received RF signal is then transmitted to digital input 8 of the Arduino board.

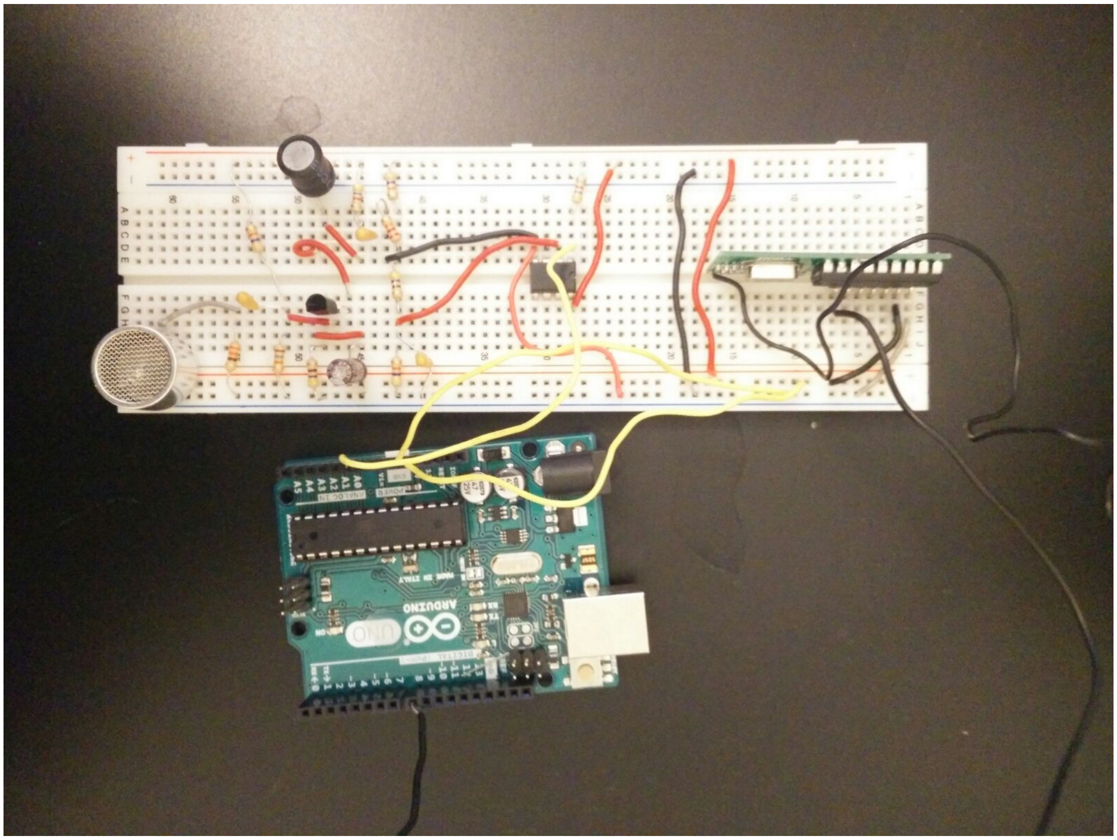

Figure 8: Assembled receiver beacon

3.3.3 Code

Arduino uses C language for programming. All the programs have two essential functions:

```
1. void setup()
2. void loop()
```

The first one allows the user to describe the pins in the board as inputs or outputs and the second one is the main function, which is repeating itself indefinitely, to the point that if you disconnect the board from the computer but power it with 5V (or 3.3V) it keeps working, as the program has been once compiled.

Emitter code In the emitter's loop() , first of all a radiofrequency wave is sent to the board through pin 8, then a delay is set, and afterwards the ultrasound wave is sent through pin 10. If the delays were not placed, there would probably exist interferences [1].

But the most important functions are the ones that enable to send the ultrasound wave or impede it [19], *startTransducer()* (which will be now explained) and *stopTransducer()*.

```
void startTransducer(float freq, float dutyCycle)
{
  if (dutyCycle > 0.5) dutyCycle = 0.5;
  else if (dutyCycle < 0) dutyCycle = 0;

  cli();
  TCCR1B = _BV(WGM13) | _BV(CS10) | _BV(ICNC1);
  long topv = (long) ((float) F_CPU /(freq * 2.0 * 1.0));
  ICR1 = topv;
  OCR1A = (int) ((float) topv * dutyCycle);
  OCR1B = (int) ((float) topv * (1 - dutyCycle));
  DDRB |= _BV(PORTB1) | _BV(PORTB2);
  TCCR1A = _BV(COM1A1) | _BV(COM1B1);
  sei();
}
```

The parameters in the top of the function (float freq) allow the user to determine the frequency of the ultrasound transducers. In the case of the circuit developed, it was 40kHz. The cli() function and the sei() function disable and enable interrupts, respectively [7].

The TCCR1B and TCCR1A are timers type 1, able to generate two pwm signals at the same time, and the parameters next to them edit their configuration [17].

TCCR1B parameters

- WGM13 decides the mode of the timer. There are also WGM10, WGM11 and WGM13. Depending on the binary value they get, the mode of the timer changes. In this case there is WGM13=1 and the others are 0. The same process will happen with the other parameters.

- CS10 (together with CS11 and CS12) slow down the frequency of the microcontroller with a prescaler. In the project there's no prescaler as it has been thought more convenient.

- The last parameter, ICNC1, determines that in the input capture pin 4 samples are taken each time [2].

Apart from the parameters mentioned, ICR1 is the Input Capture Register and OCR1 and OCR2 are the Output Compare Registers. DDRB establishes the port to use.

Receiver code In the receiver's loop(), when a radiofrequency wave is received (pin 8 is high) *Arduino* stores the time at which the RF wave has arrived (t-Start) and then (after the waiting delay) starts to receive the ultrasound wave. When the board reads a value closer to 0 from input A0, the analog input where the amplified wave can be read (Section 3.3.2. Electronic circuit) it means it's reading the maximum peak of the wave, so it stores the time (t-peak) and then calculates the time difference between the ultrasonic wave and the radiofrequency one (t= t-peak - t-start), which should vary with distance, as the velocity of the ultrasound is considered to be constant and equivalent to the speed of sound. Considering all the computed data, the distance between the emitter and the beacon can be calculated as:

$$t \cdot SpeedSound = distance$$

As some delay has been introduced in the emitter's program in order to avoid interferences, the distance value given is not the real one. In consequence, an adjusting factor should be experimentally determined and applied.

3.3.4 Radio frequency tests

Previously to the assembly of the distance measurement system, the separate modules were experimented to check they were functioning properly.

To test out the radio frequency module, both the transmitter and the receiver were connected to separate Arduino boards and moved away from each other. The RF wave emitter has 6 pins, four of which are digital pins (D0,D1,D2 and D3) that are mirrored on the receiver board. When the Arduino Uno attached to the transmitter sets a digital channel like D0 to HIGH and shortly after, when the signal arrives at the receiver, the last will output the same state as the emitter through the same pin, D0. The remaining pins are ground (GND) and power (Vcc/Vdd). The transmitter has an additional pin labeled VT that is set to high whenever at least one of the digital pins is at +5V [10].

Figure 9: 433 MHz Radio Frequency Module: Transmitter and Receiver

The testing consisted in connecting the RF transmitter's pin D0 to Arduino Uno and setting it to HIGH for 3 seconds and LOW for 12 seconds. The receiver circuit had the same digital channel pin connected to another Arduino Uno. A program was uploaded that displayed on screen the Serial port of the receiver. The program printed on screen the values from the digital pin and whenever a RF wave arrived, the values were different from null. At the testing the antennas of both transmitter and receiver were stretched out for better signal reception and several distances from 0.2 to 10 metres were sampled. The modules are supposed to communicate to up to 2 kilometres, but as for this distance is greater than the necessary for the aimed project it was not tested. The modules worked within the needed range.

In the next figure the outputs obtained in the serial monitor can be observed:

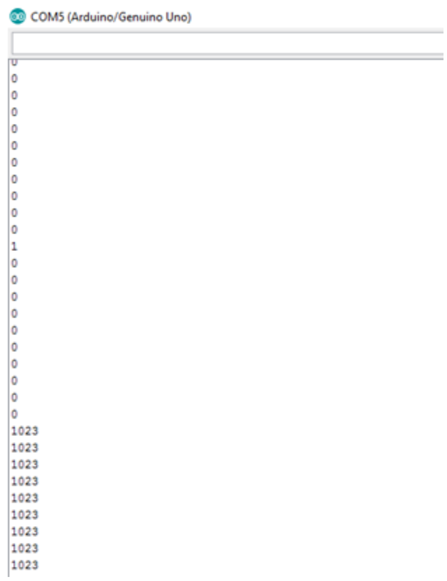

Figure 10: Outputs obtained in the serial monitor during the rf tests

3.3.5 Ultrasound tests

The first step to take when receiving the ultrasound transducers (400ST160, which can indistinctly work as emitter or receiver) is to test them to prove that they work correctly as well as to know about the kind of wave which is emitted and received.

To this aim, an oscilloscope needs to be used. A circuit and a program are also required to engage the ultrasound modules. So that, the circuit utilized is the same as the used in the project and which has been previously explained. Notice that no program needs to be executed to the receiver, the amplified wave (thanks to the circuit) can be directly read by the oscilloscope; on the other hand, to make possible the ultrasounds waves the emitter requires a program. Specifically, the emitter program was the same as explained before but changing the previous void loop function by the following.

```
void loop()
{
  startTransducer(40000.0, 0.5);
  delay(5000);
  stopTransducer();
  delay(3000);
}
```

In this case, the ultrasound wave is emitted during five seconds and stops the transmission for the next three. The proper functioning of the program should be shown in the oscilloscope display. In the next image, captured from the oscilloscope the transmitted and received wave can be observed . At the bottom the emitted wave (5V) can be seen, whereas the top view corresponds to the received wave (1V).

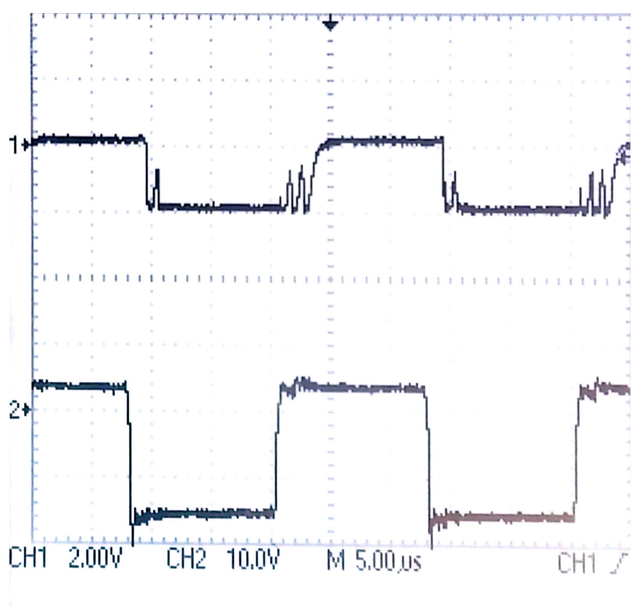

Figure 11: oscilloscope

It is to notice that there is some noise which mainly affects the received wave. Notwithstanding, it should not influence when reading the peak value (as it is done in the program) because it is higher than the noise biggest value.

Another aspect to take into account is the highest distance between the ultrasound emitter and receiver at which the wave can be correctly perceived. Judging by the findings, this distance is four meters. It does not mean that being at more than these meters the receiver is not going to perceive anything, but the signal would be weak and not reliable. To solve this inconvenient, more powerful ultrasound modules would be required.

3.3.6 General tests and data analysis

After testing the radio frequency and ultrasound modules it is time to join them to find where the *Loclock* is located. As explained beforehand, the wave's transmission between emitter and receiver will provide this information. To this end, the circuit and the code listed above must be used.

A general test would verify its proper operation by measuring a real distance and comparing it to the one given by the location system. Note that the second one should be bigger than the first because the measured time used to calculate the distances incorporates the time since the radio frequency waves were emitted and the ultrasound ones, as well as the processing time. This imbalance can be solved by processing the data with statistical techniques. Doing this, other external inaccuracies might as well be solved.

After collecting some data between 30 cm to 400 cm, it has been observed how the distance calculated slightly increases as long as the real distance does (distances over the 4m are not considered as the results are not accurate enough). Nevertheless, the intrinsic variance is greater than the maximum considered as acceptable.

The findings suggest that the variance was impermissible for the range of distances in which the indoor positioning system was being tested. The most likely culprit is the Arduino speed when reading the data and executing the receiver program. However, this fact would not be a problem when working with more powerful ultrasound modules and calculating larger distances.

In light of the results of the general test and data analysis, the team proposes below an alternative to get the indoor positioning in a more accurate way.

3.3.7 Final positioning module

As it has been aforementioned, the results of thorough testing the positioning module or distance measurement system did not yield positive results. Given that the system was incapable of giving accurate distances, the locating system had to be rethought. On this account the team traced back to the root idea that pushed the need and use of a locating system.

The purpose of the previous indoor locating system was to give accurate coordinates to the nurses in case an accident was about to happen to the user of advanced age. This locating system aimed to grid the entire residence and give the nurses through a computer or mobile device the position of the elder drawn in a map by means of triangulation with two to three beacons in each room ceiling. For this setup, the theoretic amount of beacons in the nursing home would have been considerable, although still remaining to be cheap. The advantages of such a system are obvious: the coverage is almost absolute and the elder's position can be pinned down to up to centimetres, which is somewhat important in emergency situations.

However, if it was the case that the elder pressed the alarm button the nurses would already be watchful to thoroughly inspection the residence room in which the end-user is located. The decisive use of the locating system would be to deliver the actual room where the injured person needs aid. Consequently it is not crucial to determine the exact coordinates of the watch, but it's general position in a room. There were many proposed solutions, yet the most attractive involved recycling the provided technology and integrating it into the new system.

The new solution exploits the fact that ultrasonic waves can only reach reliably up to four meters due to the power given to the transducers. These sound waves are blocked by physical objects like doors and walls. Given these facts, the ultrasonic waves seem suited to the required dimensions. The watch shall again try to communicate with a beacon through ultrasonic pulses. If the communication works, then there is a clear path between the *Loclock* and the beacon and it can be concluded that the watch is in a near distance.

To this moment it has not yet been specified which of the two acts as a receiver and which one as an emitter. On the previous system the beacons emitted an RF identity through a digital channel – to determine which beacon was speaking – and after sent an ultrasonic signal. The receiver or the watch calculated the distance covered by the delay of the ultrasonic signal. By joining the distance of two beacons it would calculate the coordinates in a plane and send it via BlueTooth. The beacons would be coordinated to send the ultrasonic waves at consecutive times and these steps would be repeated in a loop.

In the current system the most intuitive approach is to set one ultrasonic emitter at the watch. The beacons act then as ultrasonic receivers and check if any ultrasonic wave has arrived. This approach gives the freedom not to use any other device. The beacon immediately knows that the ultrasonic wave comes from the watch, which would not be the case if the roles were reversed. Although the beacons hold the locating information, it still has to be communicated to the watch or the computer. Hence, the renewed usage of the radiofrequency modules. If the *Loclock* is in a near distance of a beacon positioned, say, in room 23, the beacon shall send a radiofrequency signal through the room's specific digital channel to indicate the watch it's localization. Each room would have its own channel or identity, and although the Radio frequency modules have only 4 digital pins, the RF communication can be altered and hold a much larger number of room identities. The *Loclock* will carry a radio frequency receiver.

The late proposed system for indoor positioning is far less convoluted than the first system and yet still profitable. The prototype has not yet introduced the two or more room system. This will be presented and ready for the final report.

3.4 Alarm and watch module

Another of the main functions to implement is the alarm clock. It has been decided that the alarm time has to be set by the person who uses the mobile phone, a nurse in this case, possibly without computing programming knowledge. That's the reason why it has been tried to make the commands easy.

3.4.1 Ardudroid

An application called *Ardudroid*, which fits perfectly with our objective of facilitating the data transfer between nurse and elder, has been used to set the alarms and modify them. It can be found in the *Android Playstore*.

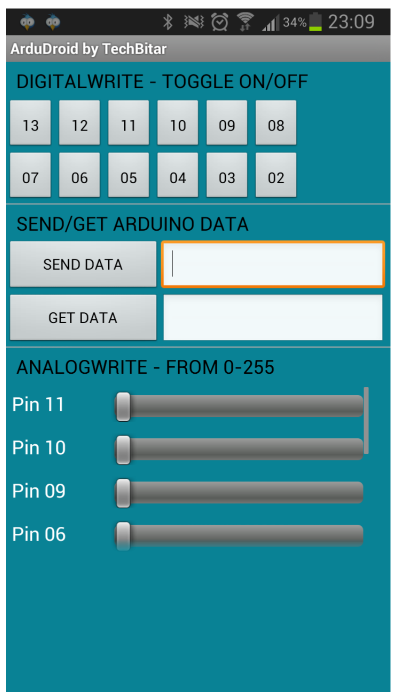

Figure 12: *Ardudroid* mobile application.

The parts used in this *app* are *SEND DATA* to transfer data to the Arduino UNO shield, *GET DATA* to know where the *Loclock* user is and *DIGITAL WRITE* to set and modify the alerts via BlueTooth.

3.4.2 Real-Time clock module

To know the current hour in each moment, it has been decided to buy a Real-Time Clock (RTC) Module. Without it, it would have been difficult to keep a measure of the time and the date.

Many options are available but, in the end, the chosen RTC module has been *Octopus Real-Time Clock*. The principal reason has been that this clock was disposed in a shop in Barcelona and it was cheaper than its competence.

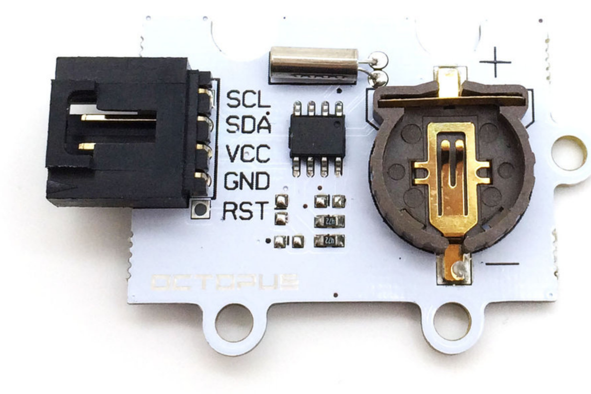

Figure 13: *Octopus Real-Time Clock*.

This module has to be set up once before its use with a function proportioned by the library *DS1307RTC.h* [8], which is essential in this part of the *Loclock* global function.

3.4.3 LCD display

As a watch, the time has to be displayed. In this case an LCD screen with 16 columns and 2 rows has been used.

This screen will print an event label of an alarm if the real time reaches the alarm time and it will also display a message if it is sent from the mobile phone application *Ardudroid*.

In case of emergency, the time won't be displayed until this S.O.S alert is disabled.

Figure 14: Time displayed on the LCD screen

Figure 15: Text message displayed on the LCD screen

3.4.4 SD card and alarm sounds

One of the distinctive characteristics of the alarms is its sound. As our watch is designed to help elders remember their routine affairs, we'll make our alarm speak pre-recorded voice notes, so that the elder knows what to do in each moment without looking at the screen. This is an important fact for users with vision problems. So, when the alarm (set before through the Ardudroid app) rings, the watch will tell the elder what to do; such as taking a shower, taking the pills, lunch time... This will make the *Loclock* more user-"friendly" and easy to use.

Our prototype is built using the Arduino technology. In the initial Arduino Starter Kit, we can find a simple buzzer. But this element isn't useful if we want to play recorded sounds. The solution is simple: save the sound files in a SD card and play them through a speaker. A SD card adapter and a speaker were purchased in order to work and play the recorded files in Arduino.

We took the Arduino Micro SD SPI expansion shield.

Figure 16: Arduino SD shield

Using this shield we'll be able to save files in a SD card and read them (play sounds in our case). We will save the sound files in a Micro SD card. A 2 Gb micro SD card is enough for our project, as the files won't take too much space.

In order to play the sounds a speaker is needed. A "+ and −" wired speaker will work.

Figure 17: Speaker

In order to play sounds through the speaker we'll need to work with the *TMRpcm.h* library [4]. With the simple command *tmrpcm.play("file name.wav")* we're able to reproduce the audio file stored in the SD card.

While putting the different code parts together we realised the *TMRpcm* library took too much space and memory, about the 50 per cent of the total available. The complete code used about the 110 per cent of the memory, making the board unstable and making it not working properly. So that, we decided to build the sound module in a separate board. If willing to put all the code together a bigger and more powerful board (such as Arduino Mega) would be needed. This could be done in future improvements.

3.4.5 Emergency notifier: red LED and button

The last function set on the watch has been the "emergency notifier", which is composed by two basic electronic elements: a LED and a button.

Figure 18: Red LED

Figure 19: Button

This part has been supported by all the other functions mentioned before. If an elder had an emergency it would be easy for him or her to warn a nurse by pressing the button of the watch. Immediately, a message will be sent to the nurse's mobile phone notifying an S.O.S alert with the time, and the red LED will be switched on. The full explication of this emergency system is explained in the user guide.

3.4.6 Code, electronic circuit and implementation

The code is divided in parts, which are related to the components mentioned in this section.

The first part and the main one is the Ardudroid function. Several modifications have been made to adapt this program to one of our main objectives: make the communication between the different devices easy. That's why a function has been implemented that reads the data sent by the mobile phone to the watch and proceeds according to the message written.

The second one makes reference to the Real-Time clock module. It consists on analyzing the time every second. The information is extracted from the *Octopus clock* which works with a battery to ensure that the watch is working despite not being connected to the board. It is important to set the time before using the clock function. The *SetTime* function can be found in the annex.

The third part is related to the LCD screen. It has been made that the time and the date has to be displayed in the screen every second. If the current time matched with the saved time of an alarm set, the event written in the Ardudroid application would be printed during ten seconds in the *Loclock*. The last case of displaying during ten seconds would be sending directly a short text message to the watch user.

The fourth one is the SD function, which enables reading documents kept inside the card and reproduces them if necessary. It is useful to communicate the event messages to the elder by voice. A speaker is needed to emit the sounds.

The last part consists on linking a button and a LED with all the functions explained before. This part is essential for the security of the elders in case of emergency.

The electronic circuit of the watch is shown in the picture below:

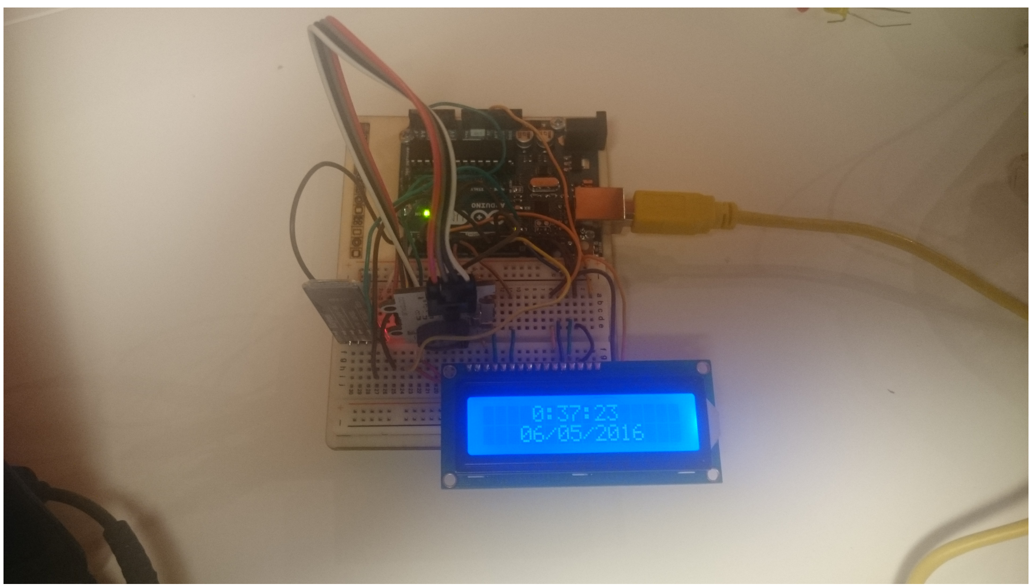

Figure 20: *Loclock* prototype circuit

3.5 Design

An important aspect to take into account when creating a new product is the design. Furthermore, when developing a gadget to elderly it needs to be user-friendly. This is the reason why *Loclock* needs to be intuitive. Moreover, the interview with the social assistant at the nursing home (Section 2. Design Thinking) revealed that old people tend to show rejection towards devices aiming to control them.

As a result, an intuitive and common device is required. To this end, elderly need to recognize the new invention. That is the reason why, *Loclock* pretends to externally look as a normal watch. Note that the device design will be used by the elderly who are quite healthy and it cannot help the ones who are seriously injured. So that, the design will be focused on the firsts.

Aside from this, there are also some technical requirements. Principally, the clock needs to incorporate a LCD so a watch with hands is not possible. In order to include all the electronic devices in the watch, the minimum clock display is 40 x 40 mm. Having a big screen can also be an advantage to the old people when reading from it.

Including all the aspects previously described, a schematic sketch was composed. Afterwards, an external designer digitized it and transformed it into the final motif using *Photoshop* and *Illustrator*.

Figure 21: *Loclock* design.

In the screen, the time and the alarms will be shown conveniently. In addition, when an alarm emerges, apart from being written in the screen, the clock *reads* it aloud thanks to the speaker which *Loclock* incorporates. Additionally, the right button shown in the previous image is the *Emergency button* which will be pressed when someone falls or needs help from a nurse.

It is to notice that this is the final design and the prototype will not be ruled by it. The prototype will focus on the functionality and not in the composition.

4 Users prototype's analysis and subsequent changes to the product

As the prototype was built, it was needed to integrate some improvements, generated as an answer to the opinion of the final users. The team talked to elder people that are not used to deal with electronic devices and people that usually take care of elder people. They all used the *Loclock* as the team had the chance to show them all its functions.

About the fact that the clock is able to remind the person the tasks he or she should do, being able to "talk" and writing in the screen the task, it was generally said that it was a great idea. The impression for the team was that the user rejected the idea of being told what to do by a person but accepted a clock if it meant avoiding obeying someone.

About the emergency button, they appreciated the function as they think falling down without receiving attention immediately is a common problem shared by elder people. In this case, the social assistant also shared her opinion. She said that just having a button is too problematic, as the people could press it involuntarily and the nurses would have too many emergency alarms. The team reacted and allowed the user to press again the button if he or she pushed it unintentionally, and the watch would warn the person while doing all these actions.

When they asked about how the nurse gets the information, we tried to explain the BlueTooth system but, unfortunately, they were concerned about the fact that if they pushed the button how could they have a 'guarantee' that the nurse had received it. Consequently, the team added a led in the circuit so when the user pushed the button it turned on, and when the nurse received the location the light started to blink and the clock showed a message telling the user that help was on its way, and thus reassuring the person in need of aid.

As only the prototype was presented and as for the moment it is too big to be considered a watch, all the people who saw it said it was necessary to make the device smaller. Unfortunately, it was not achievable for the team.

In addition, the team considered appropriate to share the product to more extended groups of people, as families play an important rule in the implementation of an electronic device in a nursing home. Consequently, a video was produced, as it was determined a powerful tool that would facilitate spreading the *Loclock* not only to possible customers but also to a crowd while sharing it in social networks. The fact allowed the team to receive feedback from people of different ages.

As a summary, the feedback was positive, as they affirmed the product was a great and innovative idea. We also had a few suggestions: an option for the direct user to know every moment where the closer nurse is in the nursing home; A tool to establish a difference between real emergencies and just calling the attention of the workers; Using the reminders also for blood pressure or glycemic tests...

We considered each idea and understood the product could be improved every day a little bit more and, of course, appreciated all the collaboration received.

5 User manual

Loclock has been designed to facilitate the communication between the watch (owned by the direct user) and the mobile phone (controlled by the indirect user). Here is an explanation of how to use *Loclock* properly.

5.1 Direct user (Elder)

The direct user has one button to press. In case of pressing it, an emergency signal with the alert sending time will be sent to the nurse.

The basic instructions that the elder has to know are explained in the diagram below:

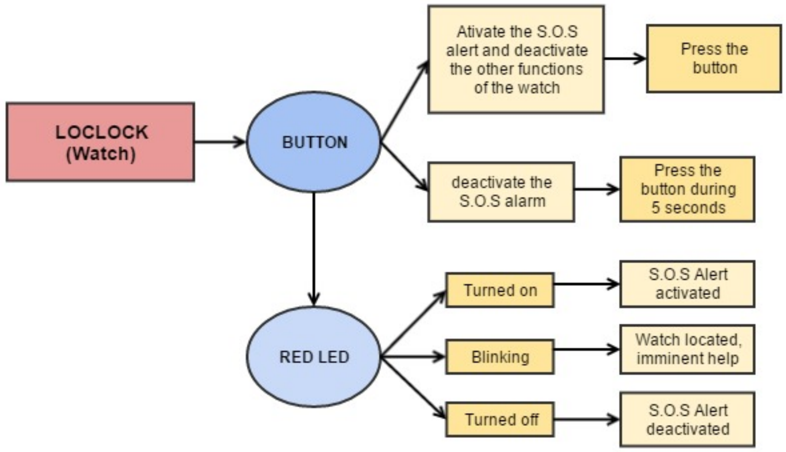

Figure 22: How to use *Loclock*.

5.2 Indirect user (Nurse)

First of all, it is indispensable to download the *Ardudroid* application, which is only available in *Android* mobiles. When the application is set up, open it and then press the three point button (bottom right of the screen) and press "connect me to a BlueTooth device". Connect the mobile with the *HC-06* device and if a password is requested, write *1234*.

Once the connection is permitted, the commands that the indirect user has to know are explained in the following diagram:

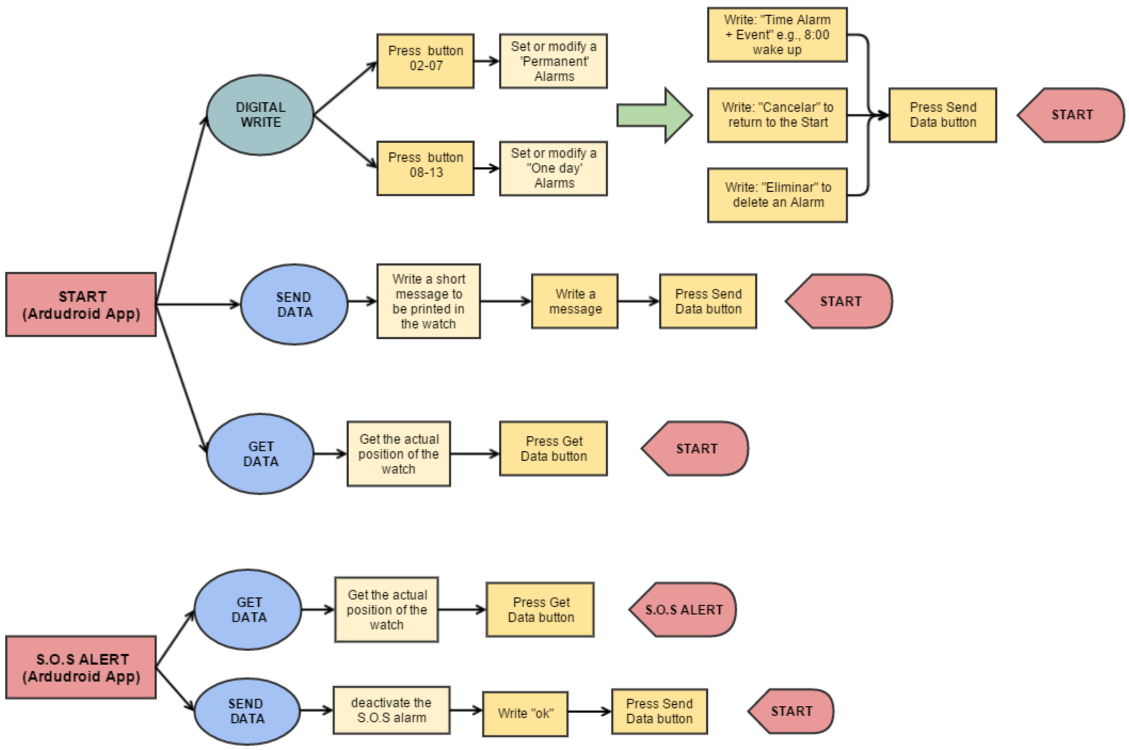

Figure 23: How to use the *Ardudroid* application.

6 Budget

While calculating the project's final cost, the materials and components bought have been considered, but also the ones which the university has provided to the team, as they should be included if the product was developed. The prize of both of them have been obtained from [11], [13], [12] and from local shops.

The material purchased has been:

Article	Price
BlueTooth Module HC-06	9,99 €
RF module	51,86 €
SD Adaptor	3,62 €
Ultrasound transducers	53,60 €
Watch module	5,08 €
Coil 33mH + Comparator LM393 + Transistors 2N3904 and 2N3906	2,95 €
Capacitors and battery adaptor	6,76 €
Coils and resistances	7 €
Boxes and other material	3 €
TOTAL	**143,86 €**

Table 3: Material budget

The material provided by the university has been:

Article	Quantity	Estimated price per unit	Total price
Arduino Starter Kit	1	89,90 €	89,90 €
Arduino uno board	3	25,00 €	75,00 €
Resistances	10	0,06 €	0,60 €
Micro SD card	1	5,00 €	5,00 €
USB connection CPU-Arduino	2	3,00 €	6,00 €
TOTAL			**176,50 €**

Table 4: Components provided by the university budget

It has also been taken into account the engineering budget, the wages paid to the team and to the project director, which can be appreciated in the next figure:

Post	Worker	Hours	Wage/hour	Total
Project Director	Cecilio Angulo	50	65,00 €	3.250,00 €
Junior engineer	Júlia Bayascas	146	44,50 €	6.497,00 €
Junior engineer	Sofía Cámara	146	44,50 €	6.497,00 €
Junior engineer	Arnau Colom	146	44,50 €	6.497,00 €
Junior engineer	Carlos Conejo	146	44,50 €	6.497,00 €
Junior engineer	Aina Galofré	146	44,50 €	6.497,00 €
TOTAL				**35.735,00 €**

Table 5: Engineering budget.

Engineering wages have been obtained from a real project developed in Mallorca (Spain) [3]. The hours spent by each member of the team also include academic training and have been an estimation. It has resulted impossible to obtain the real engineering wages that would have been paid to engineers while receiving the education, so in that amount of hours the wages have been considered the same as in useful hours.

Considering all the costs the total is 36.055,36€. This prize considers producing one *Loclock*, but if the product was produced in chain it would get very cheap, as the costs of engineering would disappear and it would be only important to consider production costs, which would reduce dramatically.

7 Conclusion

This report has tried to convey an aiding technological solution to reassure safety and provide a comforting autonomy to elder people living in nursing homes. To this end, a general overview of persisting problems in nursing homes has been gathered.

A solution has been settled in the shape of a clock, the *Loclock*. The report has followed the first steps from thought to realization of a prototype of the localization watch. Among patients and staff from a nursing home, this prototype was tested, feedback collected and included for future development. It can be inferred from conversations that elder people might benefit from a disguised device that keeps them informed of their daily activities without the commanding feeling a nurse might generate. Additionally an alarm for locating purposes in case of accidents is of great interest in the field. These features have been included in *Loclock*.

However, there are a few traits that should be considered for future development, aside from straightforward reducing the size presented in the prototype.

Other communication tools, such as Wifi, should be considered instead of Bluetooth to create a local network of watches, as for the moment a lot of beacons would be required to implement the system proposed in a nursing home. This would also help to deal with the fact that the nurse can only connect to one *Loclock* at a time.

We also considered to spread the functionality of the product not only indoors but everywhere, which could be solved with GPS system location. The mobile Application could also be further developed for easier usage and linked to computers or other devices nurses might carry (Ardudroid is not supported by *Apple* operating systems). The RF communication should also be refined to efficiently deliver the location information. The implementation of beacons ought to be studied to determine the number of beacons needed in a nursing home and possible interferences and how to avoid them.

Nonetheless, the major idea can be fully comprehended with this report and we hope that it might be a pivot for further research.

8 Annex

8.1 Datasheets

8.1.1 Arduino UNO board

Visit the page: www.arduino.cc/en/main/arduinoBoardUno

8.1.2 RF emitter/receiver pair

The related datasheet can be found on: http://pdf.datasheetcatalog.com/datasheet/PrincetonTechnologyCorp

8.1.3 Ultrasound modules

Visit the following link for further information: http://www.farnell.com/datasheets/1686089.pdf

8.1.4 LCD screen

Look at the web: www.arduino.cc/documents/datasheets/LCD-WH1602B-TMI-ET

8.1.5 BlueTooth *HC-06* module

Visit the website: www.olimex.com/Products/Components/RF/BlueTooth-SERIAL-HC-06/resources/hc06.pdf

8.1.6 *Octopus* Real-Time clock

Visit the following link: datasheets.maximintegrated.com/en/ds/DS1307.pdf

8.2 Arduino codes

8.2.1 Receiver code

```
byte a = 0;
unsigned long t_start = 0;
unsigned long t_peak = 0;
unsigned long t = 0;
const float SPEED_OF_SOUND_20C = 0.0003432; //per micro-second
float d = 0;
byte v_peak = 0;


void setup()
{
  Serial.begin(9600);
  pinMode(8, INPUT);
}
```

```
void loop()
{
  if (digitalRead(8)==HIGH)
  {
    v_peak = 0;
    t_start =micros();
    t_peak = t_start;
    delay(1);
    for (int i = 0; i < 5000; i++) {
      a = analogRead(0);
      float av= analogRead(0)/1024.0*5;
      if (av < 0.08){
        t_peak = micros();
        break;
      }
    }
    t=t_peak - t_start;
    d = (float) t * SPEED_OF_SOUND_20C;
    Serial.println("distance: ");
    Serial.println(d);
    Serial.println(" (m)\n");
  }
}
```

8.2.2 Emitter code

```
void stopTransducer()
{
  cli();
  TCCR1B = 0;
  sei();
  digitalWrite(10,LOW);
}

void startTransducer(float freq, float dutyCycle)
{
  if (dutyCycle > 0.5) dutyCycle = 0.5;
  else if (dutyCycle < 0) dutyCycle = 0;

  cli();
  TCCR1B = _BV(WGM13) | _BV(CS10) | _BV(ICNC1);
  long topv = (long) ((float) F_CPU /(freq * 2.0 * 1.0));
  ICR1 = topv;
```

```
  OCR1A = (int) ((float) topv * dutyCycle);
  OCR1B = (int) ((float) topv * (1 - dutyCycle));
  DDRB |= _BV(PORTB1) | _BV(PORTB2);
  TCCR1A = _BV(COM1A1) | _BV(COM1B1);
  sei();
}

void setup()
{
  Serial.begin(9600);
  pinMode(10, OUTPUT);
  pinMode(8, OUTPUT);
 }
void loop()
{
  digitalWrite(8, HIGH);
  delay(200);
  digitalWrite(8, LOW);
  delay(300);
  startTransducer(40000.0, 0.5);
  delay(400);
  stopTransducer();
  delay(3000);
}
```

8.2.3 Loclock principal function

If you want to see the *Loclock* global function, visit this website:
www.github.com/cconejob/Loclock-Project

References

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