BACHELOR’S THESIS

Degree in Industrial Electronics and Automatic Engineering

HOME AUTOMATION APPLICATION BASED ON ARDUINO CONTROLLABLE FROM MOBILE

VOLUME II

Report

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Resum

Aquest projecte es basa en la construcció d'una maqueta que simula una casa domòtica amb diferents modes de funcionament i que, a més, es pot controlar des de una aplicació mòbil.

Per assolir-ho, s'ha desenvolupat una casa a escala que capta diferents senyals, tant analògiques com digitals. Per acostar l'aplicació a una casa domòtica real, les variables sotmeses a estudi i control són la temperatura i la il·luminació interiors, el moviment al voltant de la casa i el nivell d'aigua de la piscina.

La casa té tres modes de funcionament principals. En mode automàtic realitza la mesura i executa el control de les variables, és a dir, s'autoregula segons les condicions a les que estigui sotmesa. En canvi, el mode remot s'assoleix mitjançant la utilització d'una aplicació mòbil que permet a l'usuari modificar les variables a lliure elecció. Per últim, en mode alarma controla els paràmetres que vetllen per la seguretat de la casa quan el propietari està absent.

Per captar els senyals el prototip té instal·lats sensors de temperatura, llum, moviment i nivell d'aigua i per la regulació i control té un ventilador, alguns LED, un avisador acústic i una bomba d'aigua. El nucli és una placa Arduino Mega que permet el funcionament de l'aplicació i que rep, a través d'una aplicació mòbil Android, ordres de mode de funcionament i, en cas de estar en mode remot, per a controlar de forma individual els diferents actuadors. Per la transmissió de dades de l'aplicació a la placa s'utilitza la comunicació via Bluetooth.

Resumen

El presente proyecto se basa en la construcción de una maqueta que simula una casa domótica con diferentes modos de funcionamiento y que, además, se puede controlar mediante una aplicación móvil.

Para conseguirlo se ha desarrollado una casa a escala que capta diferentes señales, tanto analógicas como digitales. Para acercar la aplicación a una casa domótica real las variables sometidas a estudio y control son la temperatura e iluminación interiores, el movimiento alrededor de la casa y el nivel de agua de la piscina.

La casa tiene tres modos principales de funcionamiento. En modo automático realiza la medida y ejecuta el control de las variables, es decir, se autorregula según las condiciones a las que esté sometida. En cambio, el modo remoto se consigue con la utilización de una aplicación móvil que permite al usuario modificar las variables a libre elección. Por último, en modo alarma controla los parámetros que velan por la seguridad de la casa cuando el propietario está ausente.

Para captar las señales el prototipo tiene instalados sensores de temperatura, iluminación, movimiento y nivel de agua y para la regulación y control tiene un ventilador, varios LED, un avisador acústico y una bomba de agua. El núcleo es una placa Arduino Mega que permite el funcionamiento de la aplicación y que recibe, mediante una aplicación móvil Android, órdenes de modo de funcionamiento y, en caso de estar en modo remoto, para controlar de forma individual los diferentes actuadores. Para la transmisión de datos de la aplicación a la placa se utiliza la comunicación mediante Bluetooth.

Abstract

This project is based on the construction of a model simulating a home automation with different operation modes which can be controlled also by a mobile application.

To achieve this objective, a scale house that captures different signals, both digital and analog, has been developed. To approach the house to a real home automation application the variables under study and control are interior temperature and lighting, movement around the house and water level of the pool.

The house has three main operating modes. In automatic mode, it performs the measurement and executes the control of the variables, regulating itself according to the conditions to which it is exposed. In contrast, the remote mode is achieved using the mobile application that allows user to modify the variables. Finally, in alarm mode it controls the parameters that assure the security of the house when proprietor is away from home.

To capture the signals, the prototype has temperature, lighting, movement and water level sensors installed, and for the regulation and control it has a fan, some LED, an acoustic warning device and a water pump. The core is an Arduino Mega board that allows the application operation and receives, from an Android mobile application, operating modes commands and, if it is operating remotely, orders to individually control the different actuators. For the data transmission from the mobile to the board, is used communication via Bluetooth.

Acknowledgements

At first I would like to thank my tutor for sharing his knowledge and for the support received during the project development.

Thanks to my family, without you none of this would have been possible. I owe you my degree and my strength to face every challenge.

I want also to thank my couple, for the patience and interest, for every support word.

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1. Introduction

In broad strokes, the main points of this project are automation and control, electronic boards and mobile applications and particularly home automation, Arduino boards and Android applications.

This is the result of the connection of two modern technologies, including hardware and software. Despite the actuality of these components, they all appeared long ago and have been evolving throughout history.

1.1. Origin

1.1.1. History of automation

This project is based in automation technology and more specifically in home automation systems.

Automation is the transfer of tasks normally performed by humans to a set of technological elements.
An automated system consists of two parts:

- ✓ Operation: Part formed by elements that act directly on the machine and make it perform desired operations. These elements are called actuators and some examples are engines, cylinders or photodiodes.
- ✓ Control: Brain of system, normally constituted by a programmable automaton, able to communicate with all constituents of the operation part.

The inclusion of control in the automation system, allows to decide on the development of a process, manipulating certain variables to get these or other variables to act in the desired way.

Although it seems a recent technology and currently is in full development, automation dates back to ancient times.

Nowadays nobody thinks of divine forces seeing an automatic door, it is something of the day to day that we have very internalized. It was not the same with people of Alexandria when Herón, the great genius of mechanical engineering of classical Greece, invented an automatic door opening system for a temple in Alexandria.

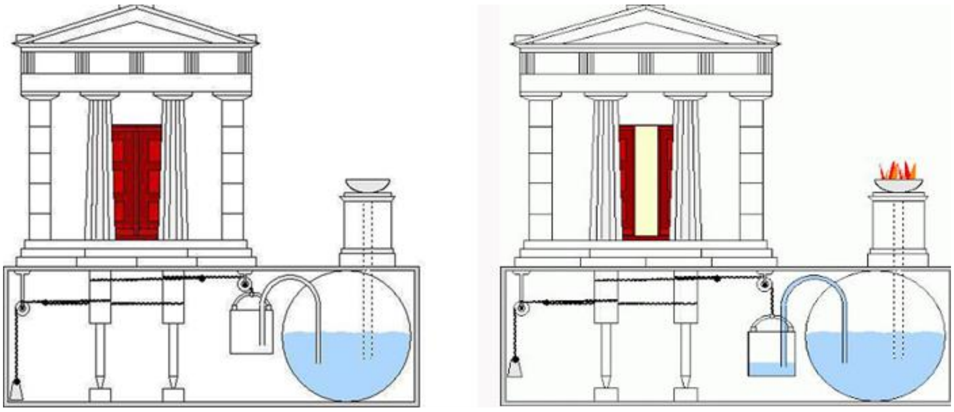


Figure 1.1.1. Automatic door designed by Herón of Alexandria.

In spite of being antecedents of automation much earlier, like Osiris statue of ancient Egypt, crankshaft and mechanic watches of the engineer Al-Jazari (1260) or automats designed by Leonardo Da Vinci (1452-1519), the industrial revolution is considered as the greatest technological, socioeconomic and cultural change in history.

It is not completely clear what year the industrial revolution began, but it is speculated that it was in 1775, when James Watt invented the steam engine. Even so, around 50's, semiconductors began to be used, fact that turned out to be a breakthrough because before this, only mechanical and electromagnetic elements were used.

In 1968 Ford and General Motors raised the specifications that had to have a programmable electronic controller to be useful in the industry, fact that arises from the need of programming to optimize processes. In addition, the company Bedford Associates developed a prototype of industrial controller obtaining what is considered as the first PLC (*Programmable Logic Controller*) in history, which was named Modular Digital Controller or MODICON, used by a car manufacturer in the United States.

Figure 1.1.2. MODICON. First PLC of the history.

Later, in the early 70's, the Intel company developed the first microprocessor, a 4-bit CPU named i4004, for the Japanese company Busicom to incorporate it into calculators and by the middle of that decade it was already incorporated into automatons. It contributed to give more flexibility because of the ease of programming, as the wired memories disappeared.

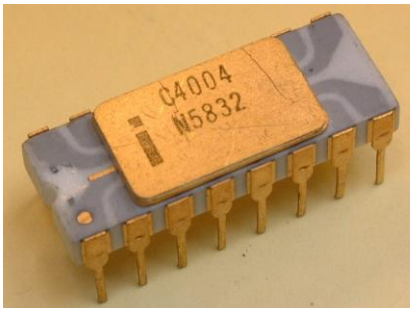


Figure 1.1.3. i4004. First microprocessor of the history.

Over years the improvements were continuous, automaton was gaining memory, ability to govern control loops, communications and programming languages became more powerful, obtaining faster processing speed, more complex control techniques… Until nowadays, having the great number of existing automatons, increasingly powerful and useful in different fields, even disengaging from the industry to open new roads, such as home automation applications.

1.1.2. Home automation applications

Houses have evolved throughout history, from caves with fire to warm and illuminate even torches and candles and finally the arrival of electricity, which has allowed to increase home comfort. Later, electronics arrived allowing the use of the appliances, being able to perform programming routines and regulation processes such as hot and cold washing or video recording.

It was from the 1970's that integrated systems were used commercially and developed into the domestic aspect of urban houses, this is when home automation manages to integrate the two necessary systems, electrical and electronic, in pursuit of the integral communication of house devices.

It was in the United States where the first devices of building automation appeared, based on the X-10 protocol. This is a communication protocol for the remote control of electrical devices, using the pre-existing electrical line to transmit control signals within home automation equipment by radio frequency pulses which represent digital information. History of automation applications comprises different stages, beginning with the first protocols oriented to remote control and following with the great protocols of self-regulation, considered the real home automation revolution.

In this way, it was obtained that a house was able to perceive different stimuli (temperature, light level, presence...) and react to them (regulate climate and lighting, activate an alarm...) while interacting with humans through different options, like mobile or PC.

At this point, is called home automation to a system capable of automate a house or building including energy management, security, comfort and communication. It can be integrated through wired or wireless communication networks, although nowadays the predominant trend is wireless. It could be defined as the integration of technology into the intelligent design of an enclosure. The main points of this technology are energy saving, comfort, security, communication and data accessibility.

Figure 1.1.4. Home automation schematic.

Nowadays thanks to the permanent technological evolution the offer is better and have grater quality, its use is now more intuitive and perfectly manageable by any user. Today's home automation contributes to increase the quality of life, makes the distribution of the house more versatile, changes environmental conditions by creating different predefined scenes and makes the home more functional by allowing the development of domestic, professional and leisure under one single roof.

1.1.3. Arduino boards

The core of this project will be an Arduino board.

Arduino boards were originally created in 2005 by Massimo Benzi of IVRAE Institute for the need to learn of the computer and electronic students. By then the acquisition of microcontroller board was expensive and did not offer adequate support, instead he obtains as a result an open-hardware board with a lot of potential and, what is more, at a very economical cost. Years later it becomes a DIY (*Do It Yourself*) technology, a great support for students.

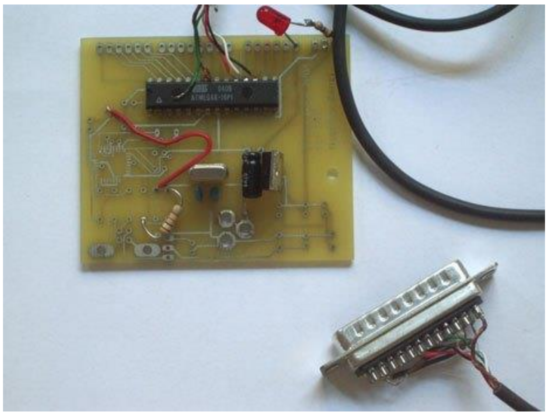


Figure 1.1.5. First prototype of Arduino developed at IVRAE institute.

Later other students joined the project, firstly Hernando Barragán, a student of Colombia University who contributes with David Mellis, other IVRAE Institute schoolmate, to the development of an environment for the programming of the processor of this board.

Over time were integrated at “Arduino Team” David Curtielles, who helped to weaken the hardware interface adding the necessary microcontrollers to integrate support and memory to the programming language in order to manipulate easily the platform, and Tom Igoe who made the board most powerful adding USB ports to connect to computers.

They began the distribution free of charge within the faculties of electronics, computing and design of the same institute. Later the publicist Gianluca Martino helped them to get promoted until Natan Sadle offered to introduce the boards in mass production.

Arduino boards has finally placed in the number one of learning tools for the development of automaton systems.

1.1.4. Mobile applications

The prototype on which this project is based can be controlled from a customized mobile application.

A mobile application is a computer application designed to be executed on smartphones, tablets and other mobile devices which allows the user to perform specific tasks of any kind, like professional, educational or social. Apps are usually available through distribution platforms operated by companies that own mobile operating systems such as Android, iOs, Blackberry or Windows Phone.

Frist mobile applications dates back to the 90’s, it can place in the first videogames, ring-tones, calendars and agendas implemented in second generation mobile phones. The popular Tetris game was the first game installed in 1994 and three years later Nokia launched the most widely accepted game named Snake. By the year 2000 the technological breakthrough of the WAP (*Wireless Application Protocol*) allowed a greater capacity for the downloading of games distributed by the telephony operators. But the App real boom came in 2008 with the launch of the Apple Store of Apple corporation, the release of the first Android SDK and the later Android Market, renamed as Google Play as a new strategic approach of Google.

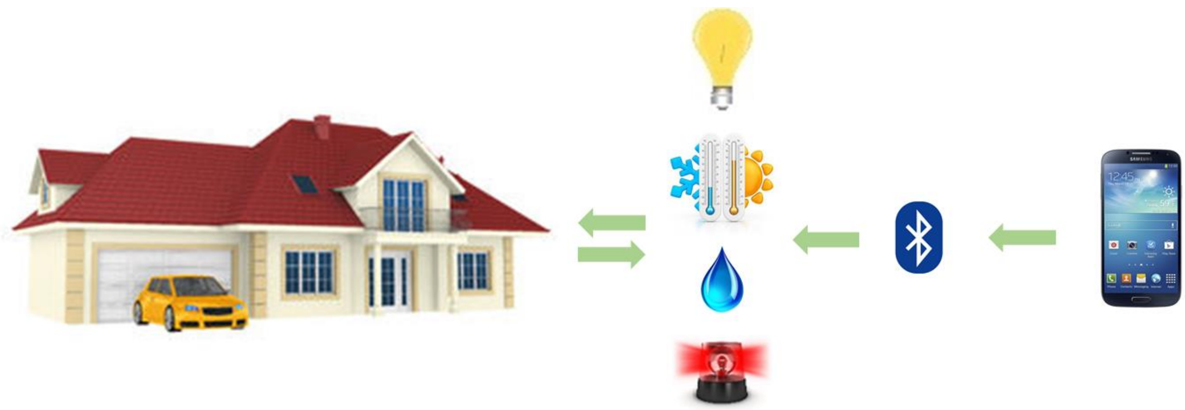
Currently, due to the applications, all functions are centralized in a small mobile device: calls, mail, social network, alarm clock, bank account, photography, GPS and a multitude of other utilities. The trend is on the raise as more and more users want to carry their life in the pocket: information, communication and personal and professional resources, all accessible at any time.

1.2. Objectives

The main objective of this project is to design and develop a prototype of a home automation controllable from an Android mobile application. Application must be able to perceive and act and to have various types of operation in order to obtain the purpose for which this technology was invented: maximizing user's comfort offering an easy way to personalize home.

The steps that should be taken to achieve the expected result are the following:

1) Determine the scope of the application and delimit the points that each mode of operation must deal with.
2) Select the components and software.
3) Electronic design.
4) Program the board.
5) Program the mobile application.
6) Build the house model.
7) Place and weld the components in the model.
8) Test and debug the application.



2. Prototype requirements

As mentioned in the previous section, in order to achieve the objectives set, first of all it is necessary to establish the needs of the project.

In hardware terms the most important part is the local controller, an Arduino board, which will be the core of the application, the one that will be communicated with the mobile application and where the sensors and actuators will be connected. The sensors needed to capture desired environmental variables are temperature, lighting, movement and water level sensors and to control these variables a fan, some LED, an acoustic warning and a water pump are required. Finally, to make effective the necessary communication between the board and the mobile will be needed a Bluetooth device.

As for software, one of the advantages of using an Arduino board as a local controller is that it has its own development environment or IDE (*Integrated Development Environment*) that provides facilities for software development. For the other programming part, will be necessary another software to program the mobile application.

3. Architecture and components

3.1. Arduino Mega

Arduino is a development board that integrates a microcontroller and its support circuitry with digital and analog inputs and outputs. It has an open source computing development platform based on an environment for programs creation.

3.1.1. Choice of board

Shown below there is a comparison chart with the commonly used boards for this type of application including their most important characteristics.

Table 3.1. Arduino boards comparison chart.

ARDUINO BOARD	Microcontroller	Input voltage	Operating voltage	Output current	Clock frequency	Flash memory	SRAM	EEPROM	Digital I/O	PWM outputs	Analog inputs
DUE	AT91SAM3X8E	7-12 V	3,3 V	130 mA	84 MHz	512 KB	96 KB		54	12	12
LEONARDO	ATmega32u4	7-12 V	5 V	40 mA	16 MHz	32 KB	2,5 KB	1 KB	20	7	12
MEGA	**ATmega2560**	**7-12 V**	**5 V**	**20 mA**	**16 MHz**	**256 KB**	**8 KB**	**4 KB**	**54**	**12**	**16**
PRO	ATmega328	5-12 V	5 V	40 mA	8 MHz	32 KB	2 KB	1 KB	14	6	6
UNO	ATmega328P	7-12 V	5 V	20 mA	16 MHz	32 KB	2 KB	1 KB	14	6	6

- Election parameters:

1) Pins:

One of the most important characteristics to keep in mind when choosing an Arduino board is the number of inputs and outputs. It can be digital or analog, depending on the application it is more important to pay attention in one type or another, but usually one parameter depends on the other, if the board has an important number of digital inputs, the analog input number will be considerable too because it normally has relation with the size of the board.

In this case, both digital and analog pins matter because the project involves digital and analog components and all of them will be connected to the board, the core of the application and the responsible of the information collection. Taking into account that the two types of pins are needed, that the project has 14 components and that the number could increase with the progress of the project, the best option is to choose a board which contains more pins than are needed at the beginning of the project so that at the end there is no risk of missing. Then **the orange shaded types** are discarded for having a pin number very fair for the scope of the project.

2) Memory:

Flash memory is the program space, where the program is stored. At the beginning of the project, without knowing what programming will behave in terms of size, and knowing that the application will have several operation modes and can grow as project progress, the safest way to avoid having to go back in an advanced stage is to ensure that the memory will be sufficient. For this reason, **the yellow shaded types** are discarded for having less KB of flash memory.

SRAM (*Static Random Access Memory*) is a type of volatile memory where program is stored and it manipulates variables when executing. The information stored will be delated when the power is lost since this memory is only for the program execution. If SRAM run out of space, the program will fail unexpectedly, even if it is compiled and uploaded to board correctly the application will not run or be run in an unwanted way. This is a very important point to have a fully functional application, so **the blue shaded types** are marked for having few KB of this memory.

EEPROM (*Electrically Erasable Programmable Read-Only Memory*) memory is a RAM memory programmable and electrically erasable, unlike the EPROM that must be erasable by ultraviolet rays. Is a non-volatile memory, it means that is capable to retrieve data after power down. **Arduino Due has no EEPROM** and although it is not planned to use, is a parameter that should also be evaluated in case that to keep the values stored after a possible loss of power becomes necessary.

3) <u>Clock frequency</u>:

Clock frequency refers at which speed CPU (*Central Processing Unit*) is running and is an indicator of the processor's speed. In this case the slowest is **Arduino Pro**.

4) <u>Operating voltage</u>:

The only board which has an operating voltage different than 5 V is **Arduino Due**, this is a major disadvantage in terms of hardware, as all components planned to be used operate at 5 V.

As a summary and final decision, it is considered that the most suitable Arduino board for this project is **Arduino Mega**. On the one hand, it is quite similar to Arduino UNO in terms of electronic characteristics but contains many more pins, and on the other hand, Arduino Due is the most powerful board in this range but it presents a problem due to hardware incompatibility with project components.

3.1.2. Parts of Arduino Mega board

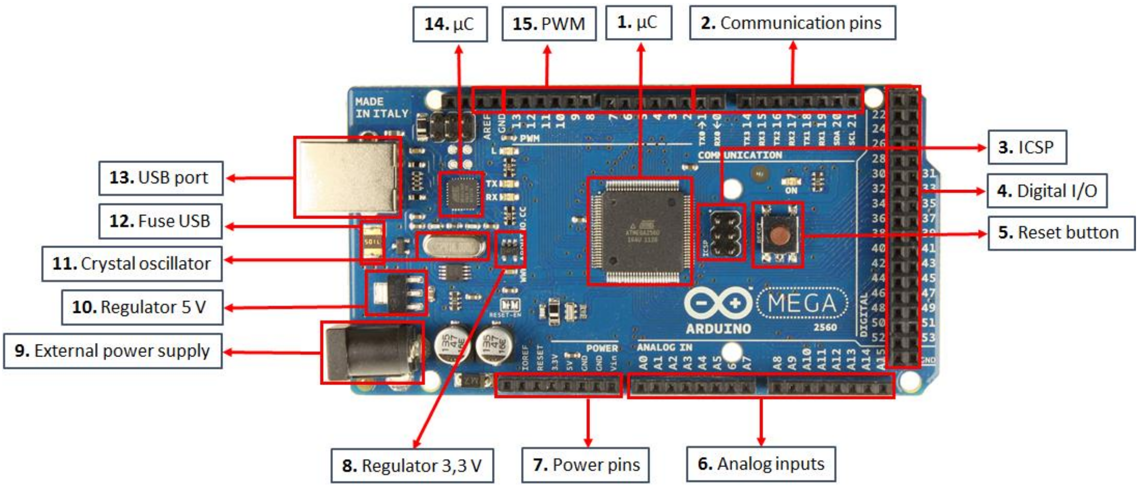


Figure 3.1.1. Arduino Mega board.

1. <u>µC</u>:

This board is based on the ATmega2560 microcontroller.

Table 3.2. ATmega256 configuration summary.

Device	Flash memory	EEPROM	RAM	General purpose I/O pins	16-bit resolution PWM channels	Serial UART	ADC channels
ATmega2560	256 KB	4 KB	8 KB	70	12	4	16

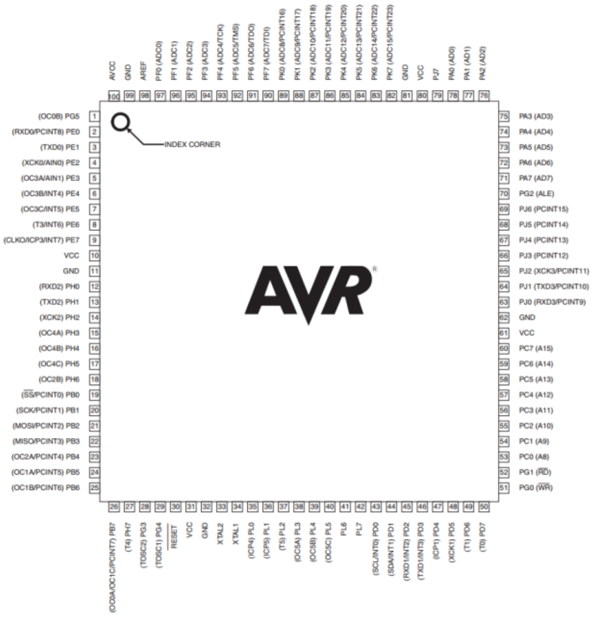


Figure 3.1.2. ATmega2560 pinout.

This microcontroller uses AVR technology, created by Atmel manufacturer, which belongs to RISC (*Reduced Instruction Set Computer*) microcontrollers family. In computational architecture, RISC is a type of CPU design with fixed size instructions presented in a reduced number of formats, in which only the loading and storage instructions access the data memory and with many general purpose registers.

The goal of this architecture is to enable segmentation and parallelism in the instruction execution and reduce access to memory.

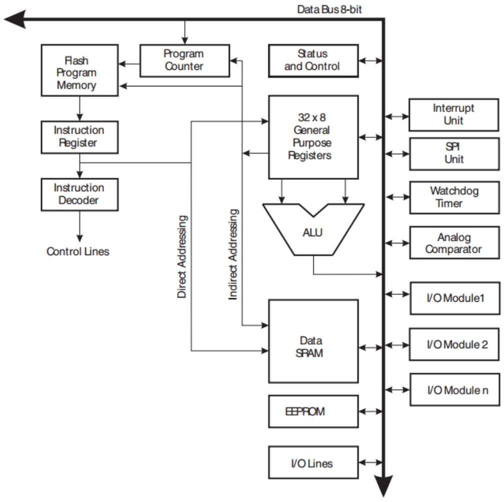


Figure 3.1.3. Block diagram of AVR architecture.

2. Communication pins:

Arduino Mega with ATmega2560 has facilities for communicating with the computer, another board or other microcontrollers, provides 4 hardware UART for TTL serial communication:

Pin 0 (RX0) and 1 (TX0), pin 19 (RX1) and 18 (TX1), pin 17 (RX2) and 16 (TX2), pin 15 (RX3) and 14 (TX3). These are used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the FTDI USB-to-TTL Serial chip.

3. ICSP:

In Chip Serial Programmer, is an input that has access to the program memory (flash) of AVR. It can upload directly from PC to a microcontroller any program without using the USB port. It is useful to work with an external AVR microcontroller completely blank without bootloader.

4. Digital I/O:

This board contains 54 digital I/O pins, 12 of which are PWM (*Pulse Width Modulation*) outputs.

5. Reset button:

The physical press of this button allows to reset, one of the hardware flow control lines is connected to the reset line of the ATmega2560 via 100 nanofarad capacitor. When this line is asserted, the reset line drops long enough to reset the chip.

6. Analog inputs:

This board contains 16 analog inputs, each of which provide 16-bit resolution. By default is measuring from ground (0 V reference) to 5 V, though is it possible to change the range using the AREF pin or *analogReference*() function by code.

7. Power pins:

Vin → when an external power source is used, voltage can be supplied using this pin.

GND → ground pin, 0 V reference.

5 V → the regulated power supply used to power the microcontroller and other components on the board. This can come either from Vin via an on-board regulator or be supplied by USB or another regulated 5V supply.

3 V → a 3 V supply generated by on-board chip, with a maximum current of 50 mA.

IOREF → the value connected to his pin will work as a voltage reference.

8. Regulator 3,3 V:

This electronic component delivers 3,3 V and if it receives more voltage is absorbed and dissipated to avoid component damaging.

9. External power supply:

It can be powered by USB or with an external supply of 6 to 20 V.

10. Regulator 5 V:

It has de same function as 3,3 V one but operating with 5 V, in case of being supplied by this voltage.

11. Crystal oscillator:

Arduino Mega's clock oscillator has a 16 MHz clock speed.

12. Fuse USB:

The Arduino Mega has a resettable polyfuse to protect computer's USB port. If more than 500 mA is applied, the fuse will automatically break the connection until the short or overload is removed.

13. USB port:

USB port can be used to power the board and to load the code.

14. µC:

ATMEGA16U2 microcontroller allows the ability to upload binary code generated after compiling the program developed by the user.

15. PWM:

Type of digital outputs used to modify the cycle of a periodical signal.

3.2. Components

3.2.1. Sensors

➢ **LM35 temperature sensor**

Integrated circuit temperature sensor with linear analog output proportional to the Centigrade temperature. It has low input impedance and an accurate calibration. The most common encapsulation is TO-92, used in low-power transistors.

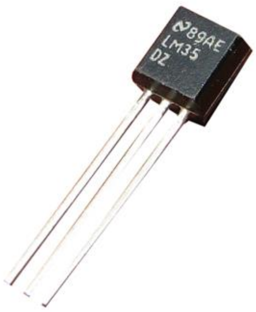


Figure 3.2.1. LM35 temperature sensor.

<u>Main characteristics</u>:

- ✓ Supply voltage: 4 – 30 V
- ✓ Current drain: less than 60 µA
- ✓ Linear scale factor: 10 mV/ºC
- ✓ Range: -55 – 150 ºC
- ✓ Accuracy: ±1/4

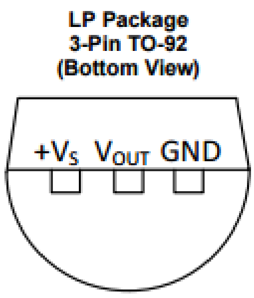


Figure 3.2.2. LM35 sensor pinout.

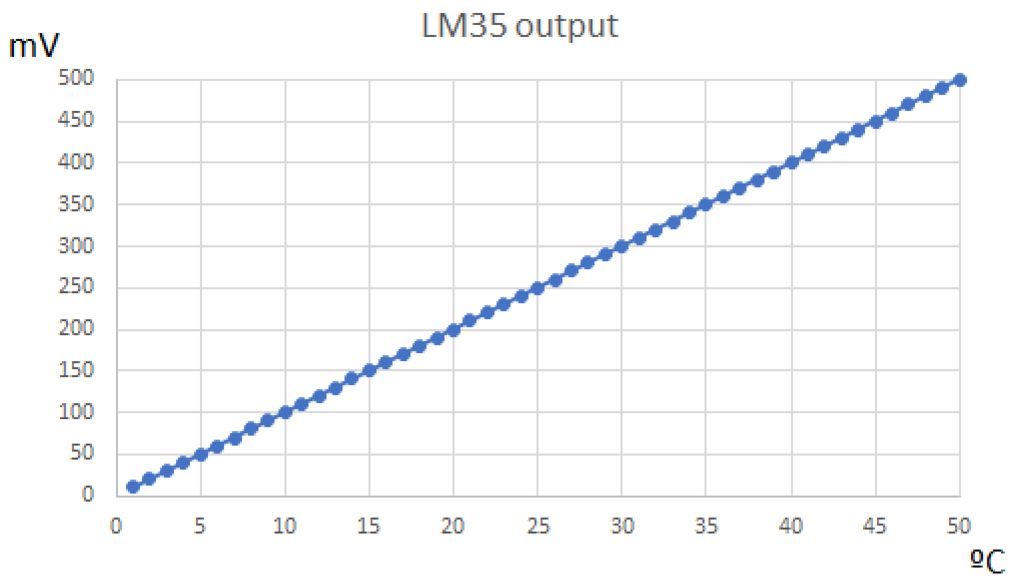


Figure 3.2.3. Voltage as function of temperature.

➢ **LDR lighting sensor**

LDR (*Light Dependent Resistor*) is a resistor which value changes depending on the light received, although its resistance value also changes depending on the infrared and ultraviolet lights. These sensors are made of cadmium that reacts to light, allowing electrons to move freely and the current to pass through it, the resistance value can pass from MΩ with total absence of light to a few Ω when receives direct light, in less than a second.

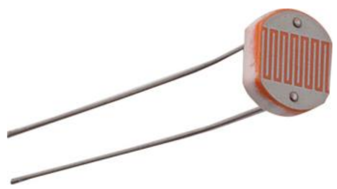


Figure 3.2.4. LDR sensor.

The relationship between the incident light captured by the sensor and the resulting resistance value is the sensitivity:

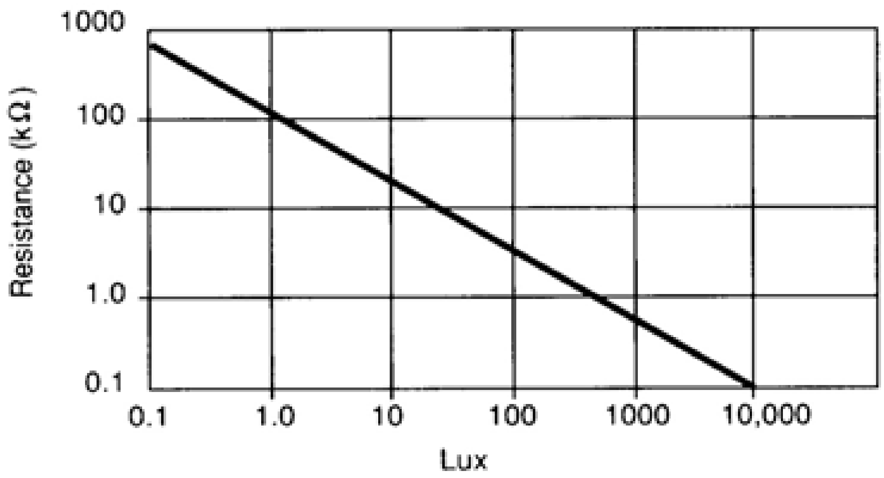


Figure 3.2.5. Resistance as function of illumination.

- **PIR motion sensor**

Motion PIR (*Passive InfraRed*) sensor reacts only to certain energy sources like head released by the human or animal bodies. Its operation is based on perceiving the difference of infrared radiation in the surrounding area.

Figure 3.2.6. PIR movement sensor.

It is constituted by a crystalline material which generates a surface electric charge when it is exposed to head in form of infrared radiation, when the quantity of radiation perceived changes, it contains a Fresnel filter which changes output in order to indicate movement in surroundings.

It also contains an amplifier, which behaves as an active filter rejecting the high frequency noise, followed by a comparator which responds to a positive and negative transitions from output sensor signal.

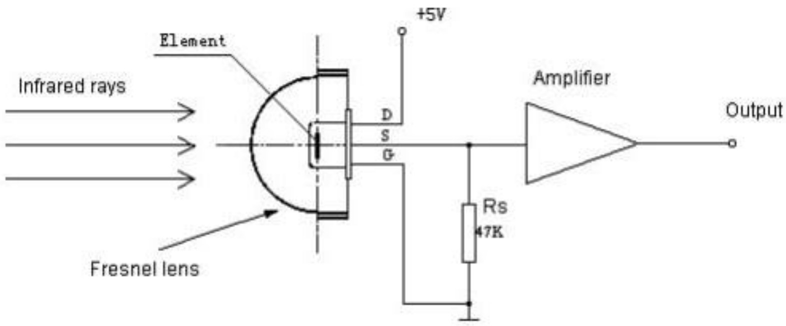


Figure 3.2.7. PIR sensor configuration.

This sensor includes detection elements configured to cancel signals caused by vibration, temperature changes or sunlight. It has two variable calibration resistors: one is for establish the time that its output is kept, the other is to vary detection distance between 3 and 7 meters.

<u>Main characteristics</u>:

- ✓ Supply voltage: 4,5 – 20 V
- ✓ Controller: PIR BISS0001
- ✓ Detection range: 3-7 m
- ✓ Fresnel lens: 19 zones, angle < 100º
- ✓ Configurable output timer by trimmer (Tx)
- ✓ Configurable retrigger by jumper

➢ **DIY T1592 water level sensor**

The principle of this sensor is to measure the size of the water droplets through the line with a serie of conductor wires exposed in parallel. This sensor give as an output 2,3 V when perceive the maximum quantity of water and 0 V with totally absence of water.

Figure 3.2.8. DIY T1592 water level sensor.

Main characteristics:

- ✓ Supply voltage: 3,3 - 5 V
- ✓ Output voltage: 0 - 2,3 V
- ✓ Working current: < 20 mA
- ✓ Detection area: 40 mm x 16 mm

3.2.2. Actuators

➢ **Fan**

Cooling fan which transmits energy to generate the necessary pressure with which a continuous flow of air is maintained. It is axial type, which means that the air inlet and outlet follow a path according to coaxial cylindrical surfaces. In this case, its brushless DC motor will be energized when the NPN transistor to which is connected saturates.

Figure 3.2.9. 5 V fan.

Main characteristics:

- ✓ Supply voltage: 3,5 - 6 V
- ✓ Current rating: 0,215 A
- ✓ Operating temperature: -10 – 10 ºC
- ✓ Fan type: axial
- ✓ Propulsion: brushless DC motor

➢ **LED**

Light Emitting Diode. Unlike diodes, LED does not use silicon crystals as a semiconductor element. It uses a combination of other semiconductor materials that emit photons of different colours when a current pass through it. It is formed by two polarities, one positive or anode and the other negative or cathode. At the junction between both a potential barrier is formed to prevent the exchange of electrons between the two regions.

When voltage is applied and LED is directly polarized, the electrons from source flows through it and whenever an excess electron negatively charged overcomes the potential barrier resistance, crosses it and it combined with a positive gap in excess. The energy acquired by the electron to cross the barrier, becomes electromagnetic energy that releases as a light photon.

Figure 3.2.10. LED.

- **Buzzer**

Is a piezoelectric transducer, a device that converts electrical signals into sound. Piezoelectric materials have the possibility of varying its volume when being crossed by electrical currents.

Figure 3.2.11. LED.

A buzzer takes advantage of this phenomenon to vibrate a membrane by traversing the piezoelectric material with an electric signal.

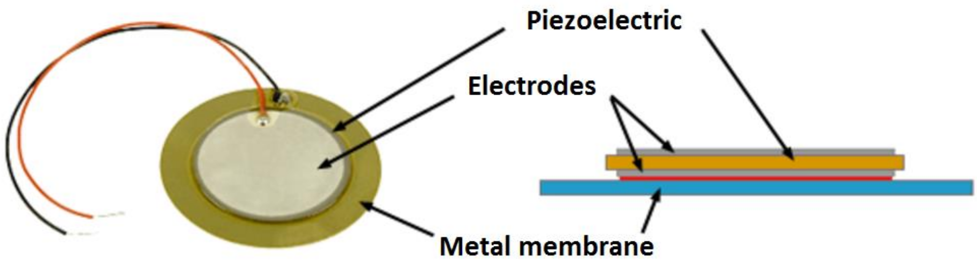


Figure 3.2.12. Buzzer structure.

➢ **Water pump**

The general features of magnetic water pumps include a rotatory impeller located in a closed case driven by a rotating magnetic field produced by individual magnets. Rotation of the impeller produces a force that drives the liquid through and out of the pump case.

Figure 3.2.13. Water pump.

Main characteristics:

- ✓ Supply voltage: 2,5 - 6 V
- ✓ Flow: 80 – 120 l/h
- ✓ Outside diameter of water outlet: 7,5 mm
- ✓ Conduction mode: brushless continuous current, magnetic conduction

3.2.3. Others

- **PCB**

Printed Circuit Board. Is a non-conductive base with a bus of conductive material. It is used on the one hand to connect electrically components using the conductive tracks, and on the other hand to hold the components using the base.

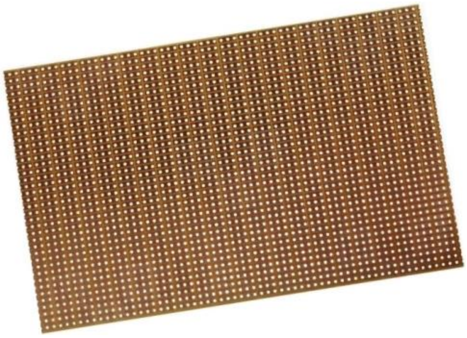


Figure 3.2.14. PCB.

- **Wires**

Element that allows closing an electrical circuit. It has to be combined with soldering.

Figure 3.2.15. Wires.

- **Resistors**

Resistors restrict the current flow in a circuit.

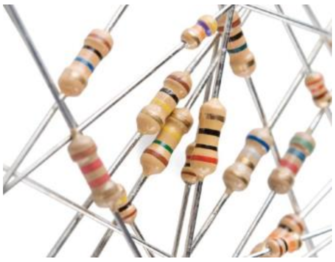


Figure 3.2.16. Resistances.

- **2N2222 transistor**

Low power bipolar transistor NPN. It is used for applications both switching and amplification. It can amplify small currents to a small or medium voltage, therefore it can only work at low power and medium frequencies.

But in this case, it is used for the switching function, in which it needs to have a certain current base so that the transistor saturates and turn the fan on to cool the sensors that have reached the threshold value. To turn the fan off, current must be null.

Figure 3.2.17. 2N2222 transistor.

3.3. Communication

To establish the communication needed between Arduino and mobile application are studied the most commonly used communication technologies.

3.3.1. Overview of standard communications

➢ **Ethernet**

Ethernet is a standard local area network with access to the medium by carrier wave detection and collision detection (CSMA/CD). It uses TCP/IP (*Transport Control Protocol/Internet Protocol*).

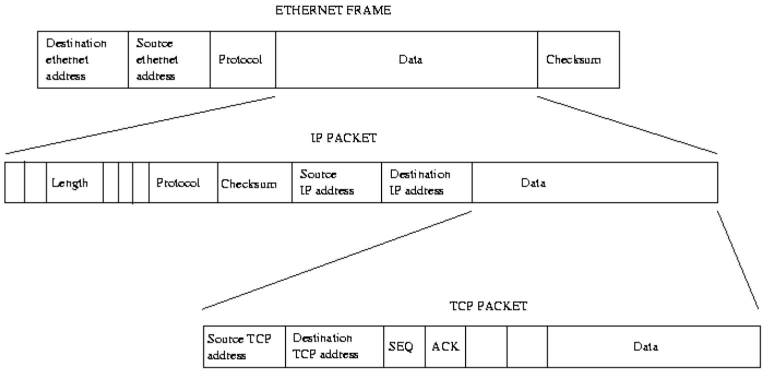


Figure 3.3.1. TCP/IP messaging.

To create a LAN (*Local Area Network*), it needs to be connected to a router with RJ45 connector and it assigns an IP address to differentiate Arduino board from other connected devices. Normally the IP is not static and every time it changes the system stops working, so it must be fixed manually by setting the MAC (*Media Access Control*) address of Arduino a fixed IP. It can be easily done entering the gateway address in the internet searcher. To use the system from anywhere is necessary to open a port to access.

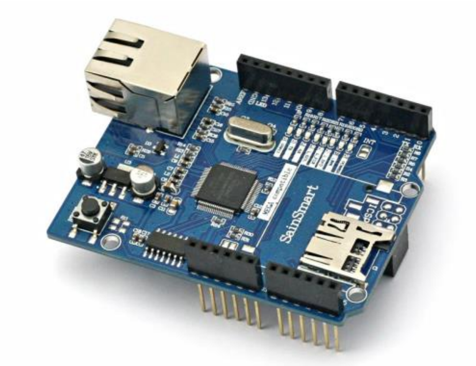


Figure 3.3.2. Ethernet shield.

- **Wi-Fi**

Wi-Fi is a WLAN (*Wireless Local Area Network*), the alternative to the wired local network that uses too TCP/IP protocol. The name is a registered brand, acronym of *Wireless Fidelity*, and there are a multitude of devices enabled to use this type of communication.

Figure 3.3.3. Wi-Fi shield.

- **ZigBee**

ZigBee is the specification of a set of high-level wireless communication protocols for use with low-power digital broadcasting based on the standard of WPAN (*Wireless Personal Area Network*). Its goal is applications that require secure communications with low data rate and maximize the life of batteries.

Xbee is the brand name of RF (*Radio Frequency*) communication module from Digi International that transmits and receives data over the air using radio signals. There are many types, some are based on the ZigBee standard and others are proprietary or standard modifications.

Figure 3.3.4. Xbee module.

- **Bluetooth**

Bluetooth is an industrial specification for WPAN (*Wireless Personal Area Network*), that enables the transmission of data and voice between different devices through a radiofrequency link in the 2.4 GHz ISM band. The main objectives to be achieved with this standard are facilitate communication between mobile devices, remove cables and connectors between them and offer the possibility to create small wireless networks facilitating the synchronization of data between personal equipment. All Bluetooth devices have a unique address of 48 bits and a device name that allows the identification of each other.

Devices that incorporate this protocol can communicate with one another when within its reach. The communications are by radiofrequency so that the devices do not have to be aligned and can even be in separate rooms if the transmission power is sufficient. These devices are classified as Class 1, Class 2 and Class 3 depending on the transmission power.

Table 3.2. Bluetooth classification by class.

Class	Maximum Power (mW)	Maximum Power (dBm)	Range
Class 1	100 mW	20 dBm	100 m
Class 2	2.5 mW	4 dBm	10 m
Class 3	1 mW	0 dBm	1 m

There are two main Bluetooth modules compatibles with Arduino and other microcontrollers: HC-05 and HC-06. These are both of Class 2 and ease to use thanks to its SPP (*Serial Port Protocol*).

Bluetooth module HC-06 is only capable to work as Slave, it means that it can be connected only to a Master and it has a reduced set of instructions which it can attend. On the other hand, Bluetooth module HC-05 is capable both to work as Slave and as Master, it can be connected to a more than one Slave and receive and request information from all of them, arbitrating the transfer of information (maximum 7 slaves) and can attend to a greater number of configuration commands.

3.3.2. Bluetooth communication

After a global communication overview, it is decided to use Bluetooth for the communication between Arduino and mobile application, more specifically HC-05 module.

This module is finally chosen to meet all application requirements. It is a wireless technology, the sender and the receiver are not physically connected, but trough electromagnetic waves. It has a range of 10 meters, enough to be able to control the variables using mobile phone, since this type of control make sense when the user is inside the house. Finally, the only additional requirement to make the communication between both devices is that the mobile phone has Bluetooth connectivity, which nowadays is a standard characteristic of mobiles.

<u>Main characteristics</u>:

- ✓ Configurable as Slave and as Master.
- ✓ Radio chip: CSR BC417143.
- ✓ Frequency: 2.4 GHz ISM band.
- ✓ Modulation: GFSK (*Gaussian Frequency Shift Keying*).
- ✓ Built-in PCB antenna.
- ✓ Emission Power: ≤ 4 dBm (Class 2).
- ✓ Range: 10 m.
- ✓ Speed: Asynchronous: 2.1 Mbps/160 kbps; Synchronous: 1 Mbps/1 Mbps.
- ✓ Security: Authentication and encryption.
- ✓ Profiles: Serial port Bluetooth.
- ✓ Current consumption: 50 mA.
- ✓ Supply voltage: 3.6 V – 6 V.
- ✓ Operation temperature: -20 ºC – 75 ºC.

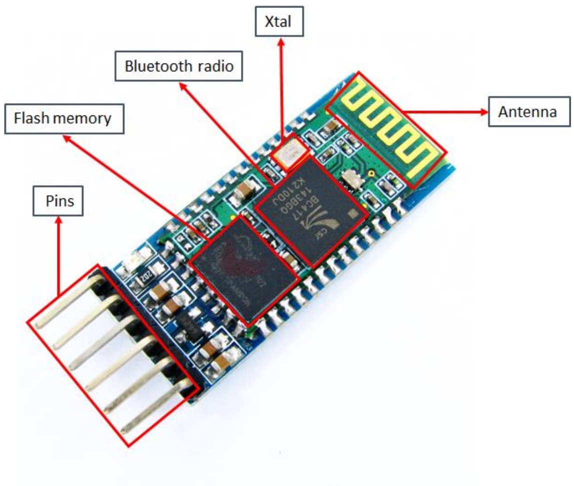


Figure 3.3.5. Bluetooth HC-05.

3.4. Mobile Application

3.4.1. Choice of software

Nowadays thanks to the boom of mobile applications there are infinite possibilities to build one. One of them is to use a software in which is not needed to know anything of code, fact that facilites access to non-experienced users, but the problem of this option is that it greatly restricts the field of action in terms of functionality and default templates are often used, which also limits user’s challenge of design own and unique mobile application. For these reasons, these types of software are discarded to be used during this project.

After this first selection, there are many software valid for the purpose of this project. The application was started to develop using Android Studio, but the lack of experience programming with Java turned the activity more difficult as the development of the application progressed.

Then it was decided that the best way to continue with the design and development was to use Google App Inventor software, an integrated development environment to create mobile applications for Android operating system. The application’s block editor uses the open blocks Java library to create a more intuitive language. The compiler that translates visual block language to Android uses Kawa as a programming language.
Its resulting applications allows to cover a great number of basic needs in a mobile device, including all the requirements for the project application, but may be limited for other applications with more complexity.

3.4.2. Functionality of the application

Mobile application is programmed to connect to a Bluetooth device to be able to send orders to Arduino board.
Once it is connected, user has to select between three main modes: Automatic, Remote and Alarm.

- **Automatic mode**

Each time the user selects this mode, the prototype has to be able to get temperature, lighting and water level values from different sensors and act according to the information collected, determined by Arduino code uploaded in its microprocessor.

The following control loops must be in operation when automatic mode is chosen in order to automate home functions:

- ✓ A fan has to be activated when the temperature value is greater than a pre-established threshold. When sensor senses that temperature is higher than the marked value, fan will be activated until temperature stabilizes below that value.

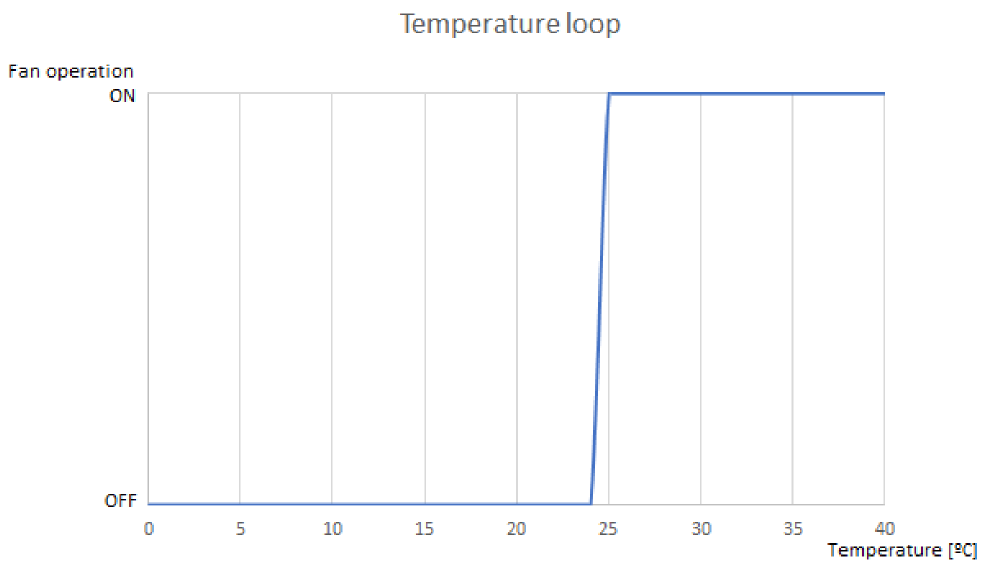


Figure 3.4.1. Graphic of temperature automatic control.

- ✓ A group of LED has to be turned on gradually when the light sensor receive less light, with the purpose of compensate the lack of natural light with artificial light. In conditions of maximum value of natural light all LED will be off, as the natural light decreases it will be compensated with artificial light to maintain the same condition. In this situation, the darker it will be, the more LED will be lighted up: with less than 20 % of natural light all LED will be on, between 20 % and 40 % three LED will be on, between 40 % and 60 % two LED will be on, between 60 % and 80 % one LED will be on and with more than 80 % all LED will be off.

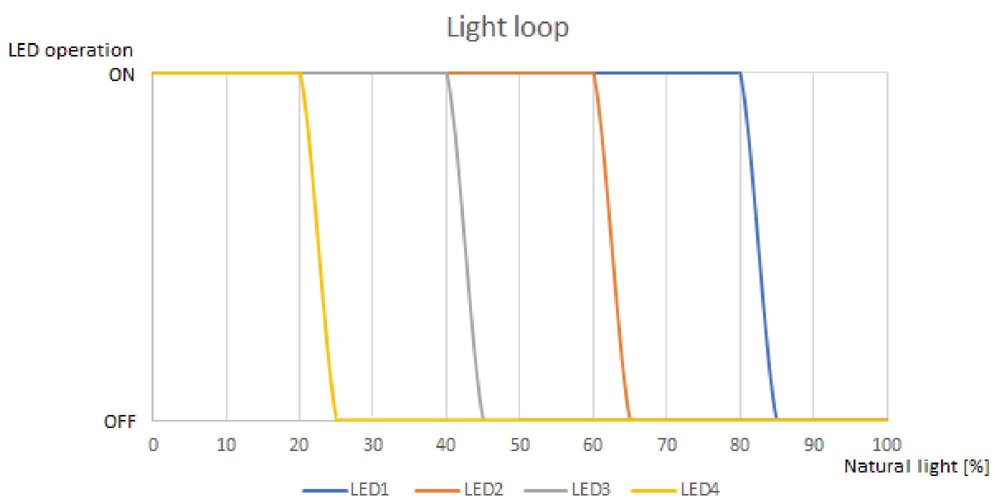


Figure 3.4.2. Graphic of lighting automatic control.

- ✓ A water pump has to be activated when the water level is greater than a pre-established threshold.

- **Remote mode**

In addition, all actuators must be controlled by a mobile application programmed specifically for this purpose and the user has to be able to let the house self-regulate its own variables or control it manually from the App, regardless of the values perceived by the sensors.

Mobile application has a section in which user can control manually the number of LED that are going to be turned on, then user can turn on or off each LED separately or turn on or off all LED on at once.

It has another section in which user can control manually the fan, regardless of the ambient temperature.

Finally, the user will also be able to control pool level activating or deactivating water pump to empty the pool to desired level.

- **Alarm mode**

When alarm mode is selected, application works with active alarm and level pool loops, to avoid water overflow in case of rain and entry of thieves into the property. In this way, if water level sensor is activated, water pump is activated until sensor stops sensing and if movement sensor detects movement around the house, an alarm is activated together with a flashing red LED.
In this case, it can be seen by the user in the application only if alarm mode is activated.

4. Electronic design

4.1. Block diagram

Below is shown the diagram block of the entire application:

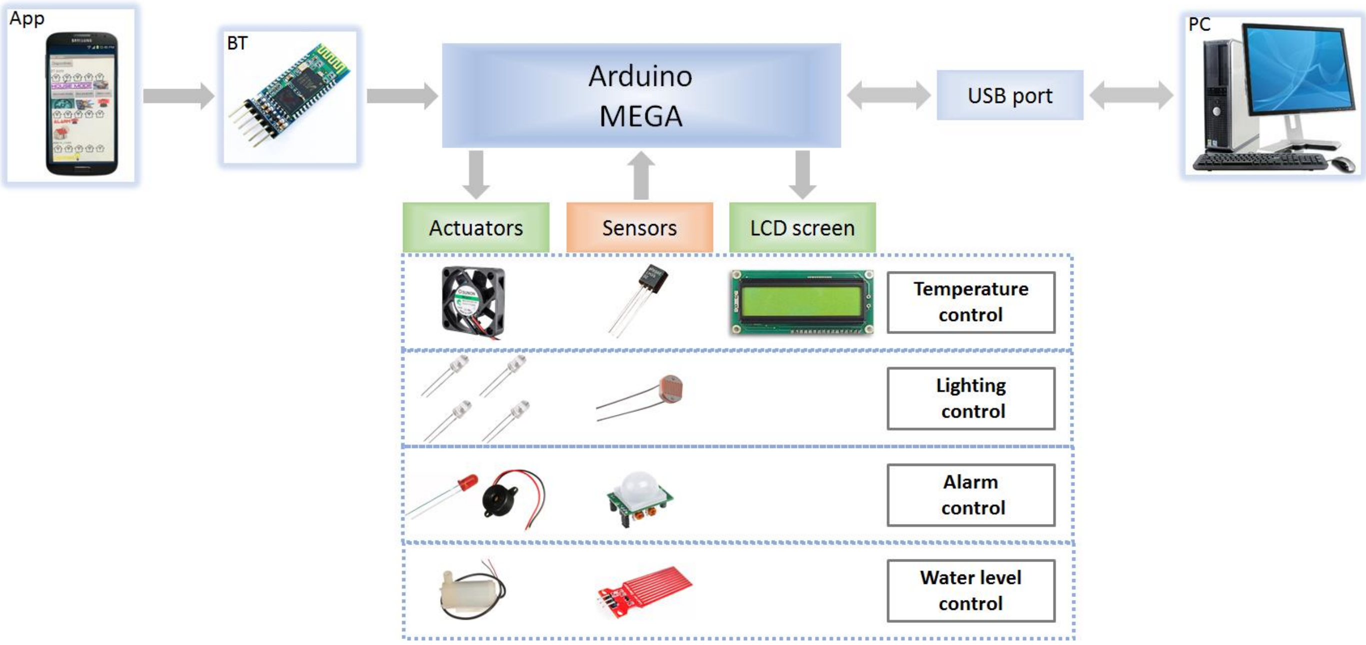


Figure 4.1.1. Block diagram of the application.

The core of the application, where all the information is centralized, is the microcontroller ATmega2560 included in the Arduino Mega board. The code is continuously executed in it and it collects all function modes, receiving orders of the mobile application, information of the environment through sensors and governing all the actuators connected after processing all the data acquired.

4.2. Component calculation

4.2.1. Temperature circuit

➢ Temperature sensor:

As is specified in ATmega2560 microcontroller datasheet of Atmel manufacturer, it incorporates a 10-bit ADC.

If is taken a temperature range of 0 to 100 ºC and LM35 temperature sensor is calibrated so that each degree Celsius is equal to 10 mV as output:

$$100\ \text{ºC} \times 10\ \text{mV} = \mathbf{1\ V} \qquad \textbf{(Eq. 4.1)}$$

At the maximum temperature the output will be 1 V and the maximum value of ADC is 5 V, so it means that a percentage of range is lost:

$$\text{resolution} = \frac{5\,V}{2^{10}} + \frac{5}{1024} = 4{,}88\,mV \qquad \textbf{(Eq. 4.2)}$$

It is possible to switch internal voltage reference of microcontroller to 1,1 V by code and in this case the resolution will be more accurate:

$$\text{resolution} = \frac{1{,}1\,V}{2^{10}} + \frac{1{,}1\,V}{1024} = 1{,}07\,mV \qquad \textbf{(Eq. 4.3)}$$

It can be reach too by adding a voltage divider or an amplifier:

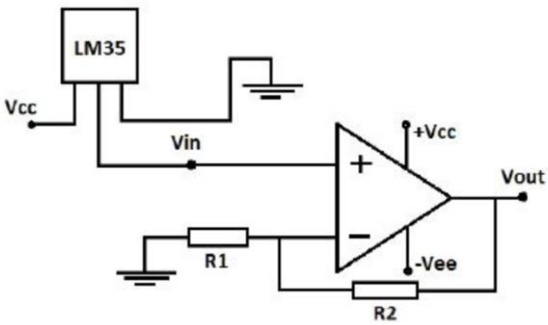


Figure 4.2.1. Amplifier.

$$V^{+} = Vin \quad \textbf{(Eq. 4.4)}$$

$$V^{-} = \frac{Vout \cdot R1}{\mathrm{R1} + \mathrm{R2}} \quad \textbf{(Eq. 4.5)}$$

$$V^{+} = V^{-} \quad \textbf{(Eq. 4.6)}$$

$$\mathrm{Gain} = \frac{Vout}{\mathrm{Vin}} = \frac{R1 + R2}{\mathrm{R1}} = 1 + \frac{R2}{\mathrm{R1}} \quad \textbf{(Eq. 4.7)}$$

$$\boldsymbol{Gain\ wanted = 5}:$$

$$5 = 1 + \frac{R2}{\mathrm{R1}} \quad \textbf{(Eq. 4.8)}$$

$$If\ R1 = \mathbf{1\ k\Omega}:$$

$$R2 = (5 - 1) \cdot 1000 = \mathbf{4\ k\Omega}$$

$$\mathbf{100\ ºC \cdot 0,05\ =\ 5V} \quad \textbf{(Eq. 4.9)}$$

In this way, in conditions of 100 ºC (maximum range value) LM35 sensor will give 5 V as output signal.

The first solution to increase resolution is dangerous for the reliability of the other analog sensors results, which must be referenced to 5 V. The code is not so fast as to be able to change for sure voltage reference on each signal reading and false values can be obtained for both sensors referenced to 5 V and 1,1 V.

The second solution is more safety for the good function of the system and it will be chosen in case of necessary, but also has disadvantages. It increases the difficulty of the circuit because it has to be powered with symmetrical voltage different than 5 V increasing the price too.

The purpose of the temperature control of this project is not to have a great temperature resolution, it is sufficient to visualize the change of whole degrees (without need of decimals) so that when the threshold is reached (typically at 25 ºC) being in automatic mode, turn on the fan. In the case of remote mode is also not necessary, as the user decide by its own thermal sensation if the fan in turned on or not. So, finally the temperature changes that can capture this project will be approximately 0,5 ºC, having an output of 0 V at 0 ºC and 1 V at 100 ºC.

- Fan:

According to fan datasheet of Sunon manufacturer, its power is 0.44 W. With this information and knowing that it is powered by 5 V:

$$\mathrm{P} = \mathrm{VI}$$ **(Eq. 4.10)**

$$I = Ic = \frac{P}{V} + \frac{0{,}44\ W}{5\ V} = 0{,}088\ A = 88\ mA$$

$$Ib = \frac{Ic}{\beta} + \frac{0{,}088\ A}{35} = 2{,}514\ mA$$ **(Eq. 4.11)**

$$\beta \rightarrow Minimum\ current\ gain\ indicated\ by\ manufacturer$$

$$\mathrm{V} = \mathrm{IR}$$ **(Eq. 4.12)**

$$R = \frac{V}{I} + \frac{5\ V}{2{,}514\ mA} = 1988{,}86\ \Omega$$

$$R\ standard \rightarrow 1800\ \Omega$$

When the pin where fan is connected receives de signal from code, it will be activated.

The fan speed is not controlled, is an all-or-nothing control, so that when fan is activated it works always at same speed.

4.2.2. Light circuit

➢ Light sensor:

By a pair of serial resistors, it is possible to distribute the voltage supplied by the source between its terminals. Using a LDR sensor it obtains a variable voltage according to the amount of light sensed, as it is shown below:

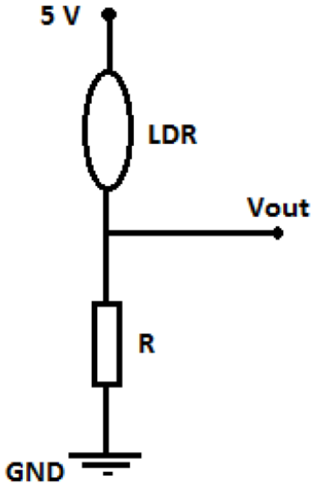


Figure 4.2.2. Voltage divider of LDR sensor.

The more light the LDR sensor receives, the less opposite resistance will have and, as a result, more current will reach the analog pin of the board. Vout changes according to the following equation:

$$Vout = \frac{R}{LDR + R} \cdot Vin$$

(Eq. 4.13)

As LDR sensor resistance decreases, Vout is greater, having the maximum value when LDR resistance is null (it is fully lighted) and the minimum value when LDR resistance has it maximum value (it is fully dark).

If R is fixed to a 1 kΩ:

✓ Situation 1: LDR fully lighted → LDR resistance value close to 0 Ω:

$$Vout = \frac{1\ k\Omega}{0 + 1\ k\Omega} 5V = 5\ \mathrm{V}$$

(Eq. 4.14)

✓ Situation 2: LDR fully dark → LDR resistance value very high MΩ:

$$Vout = \frac{1\,k\Omega}{M\Omega + 1\,k\Omega} 5V \rightarrow 0\text{ V}$$

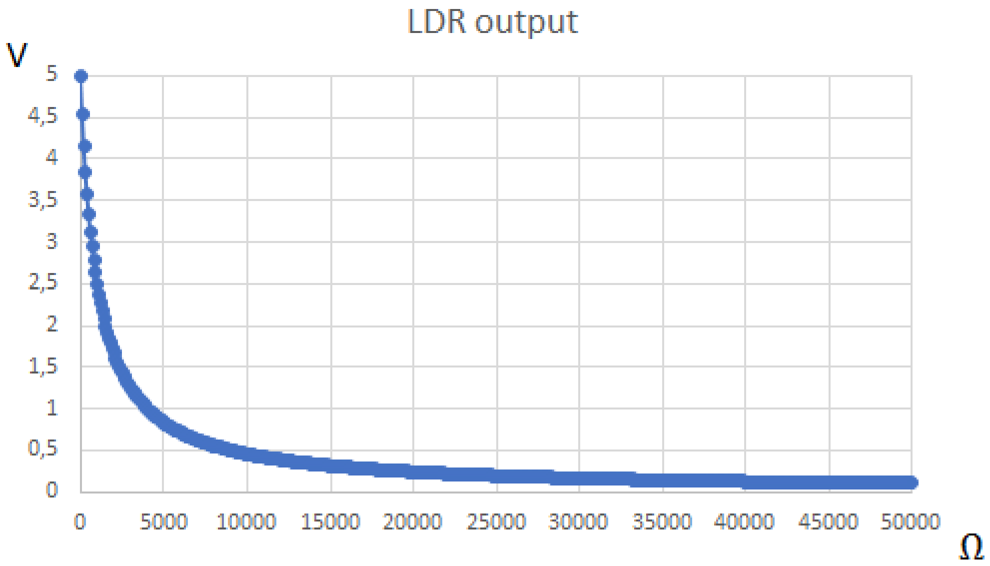


Figure 4.2.3. Voltage as function of resistance.

The microcontroller has a 10-bit ADC, so as the values of the pin where the LDR sensor is connected will be between 0 and 1024. So, with an output of 5 V ADC value will be 1024 and with an output of 0 V ADC value will be 0.

If 4 LED are used to compensate the lack of natural light with artificial one, the strategy will be the following.

Table 4.1. Lighting loop functionality according to ADC value.

ADC value	Number of LED lighted
0 – 205	4 LED ON
206 – 411	3 LED ON
412 – 616	2 LED ON
617 – 821	1 LED ON
822 – 1023	0 LED ON

- LED:

A normal LED requires a current of 15 mA approximately. Bearing in mind that the voltage loss across its terminals is 2 V and that it is powered by a voltage of 5 V, 3 V must fall in the resistor:

$$V = IR \qquad \textbf{(Eq. 4.15)}$$

$$R = \frac{V}{I} = \frac{3\,V}{15\,mA} = 200\ \Omega$$

$$R\ standard \rightarrow\ 220\Omega$$

4.2.3. Water level circuit

- Water level sensor:

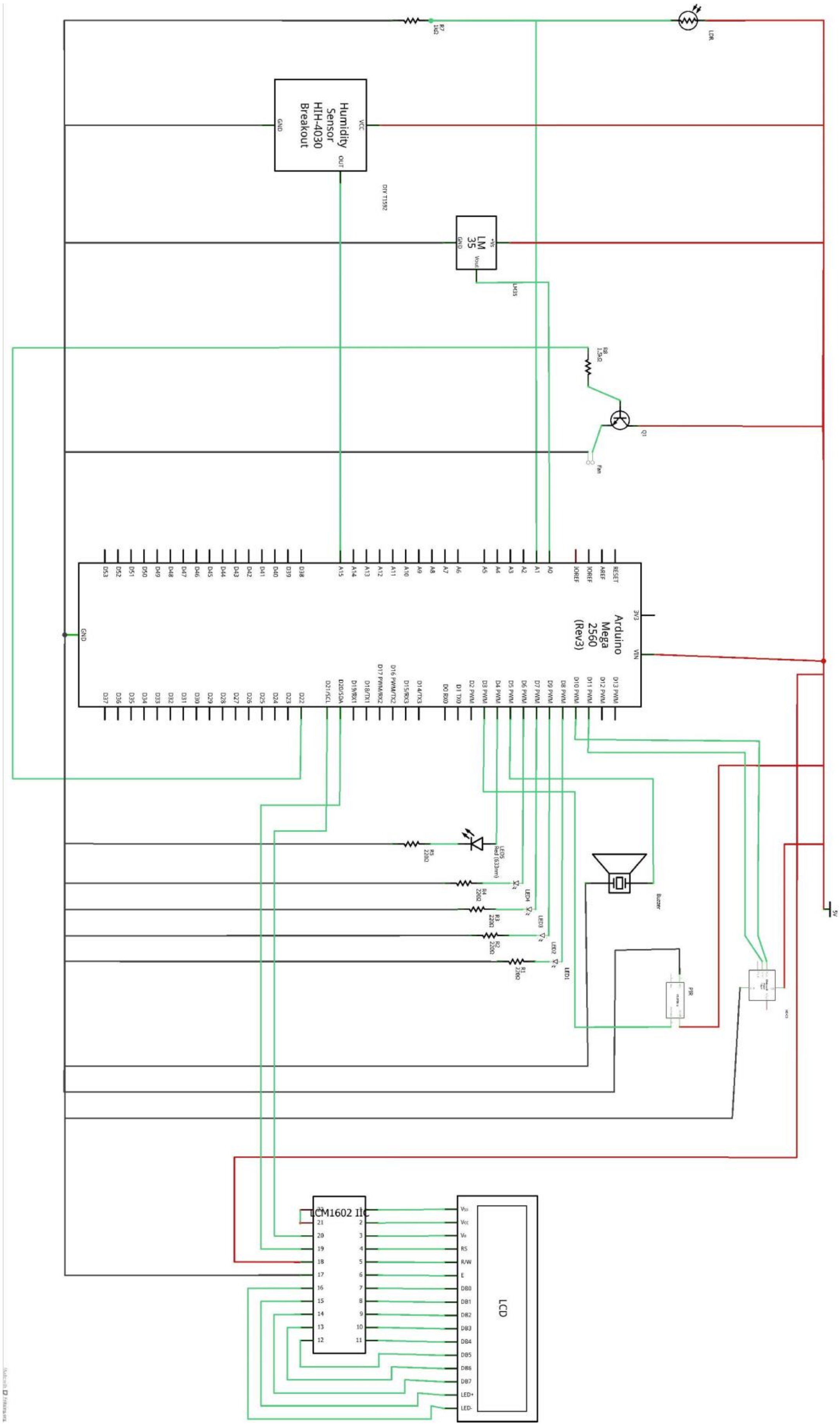
The water level sensor does not need an additional electronic circuit, it is directly connected to an analog input of the board.

When it senses the maximum quantity of water that it can perceive, its output is 2,3 V and when it does not senses a drop of water its output is 0 V. So, having a 10-bit ADC, with the maximum percentage of water sensed the value will be 1024 and 0 with the lowest.

- Water pump:

This component does not need an additional electronic circuit neither, it is connected directly to a digital pin of the board. When the water sensing conditions defined by code are reached, the water pump is activated until the water level sensed decrease its value below the activation threshold.

4.3. Electronic schematic



5. Programming

5.1. General overview of the application

To get the expected functionality of the project, the application has been programmed by dividing it into two platforms. Arduino board code is the one that collects all the information and controls actuators. The other is the code of the mobile application, that defines the operation mode all time and, in case of being in remote mode, which orders the operation of the actuators, but always acting through the microcontroller of the board.

Below is shown the block diagram of the entire application.

- **Mode choice**

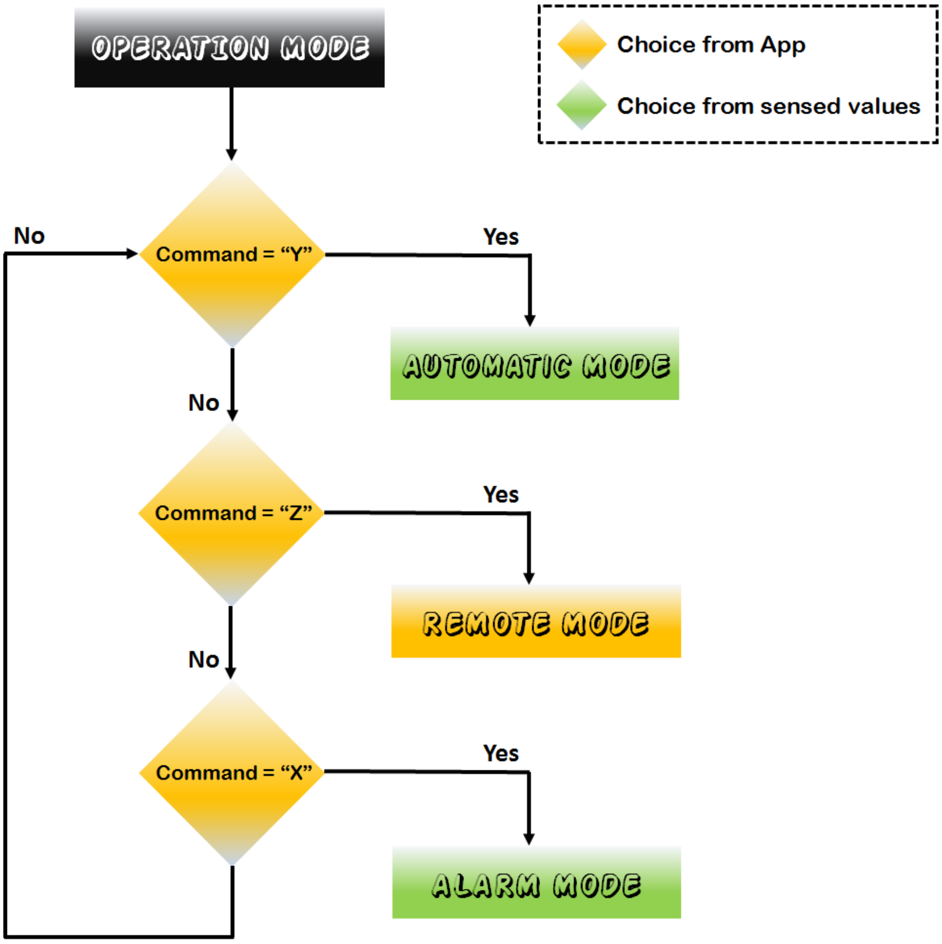


Figure 5.1.1. Mode selection chart.

- **Automatic mode**

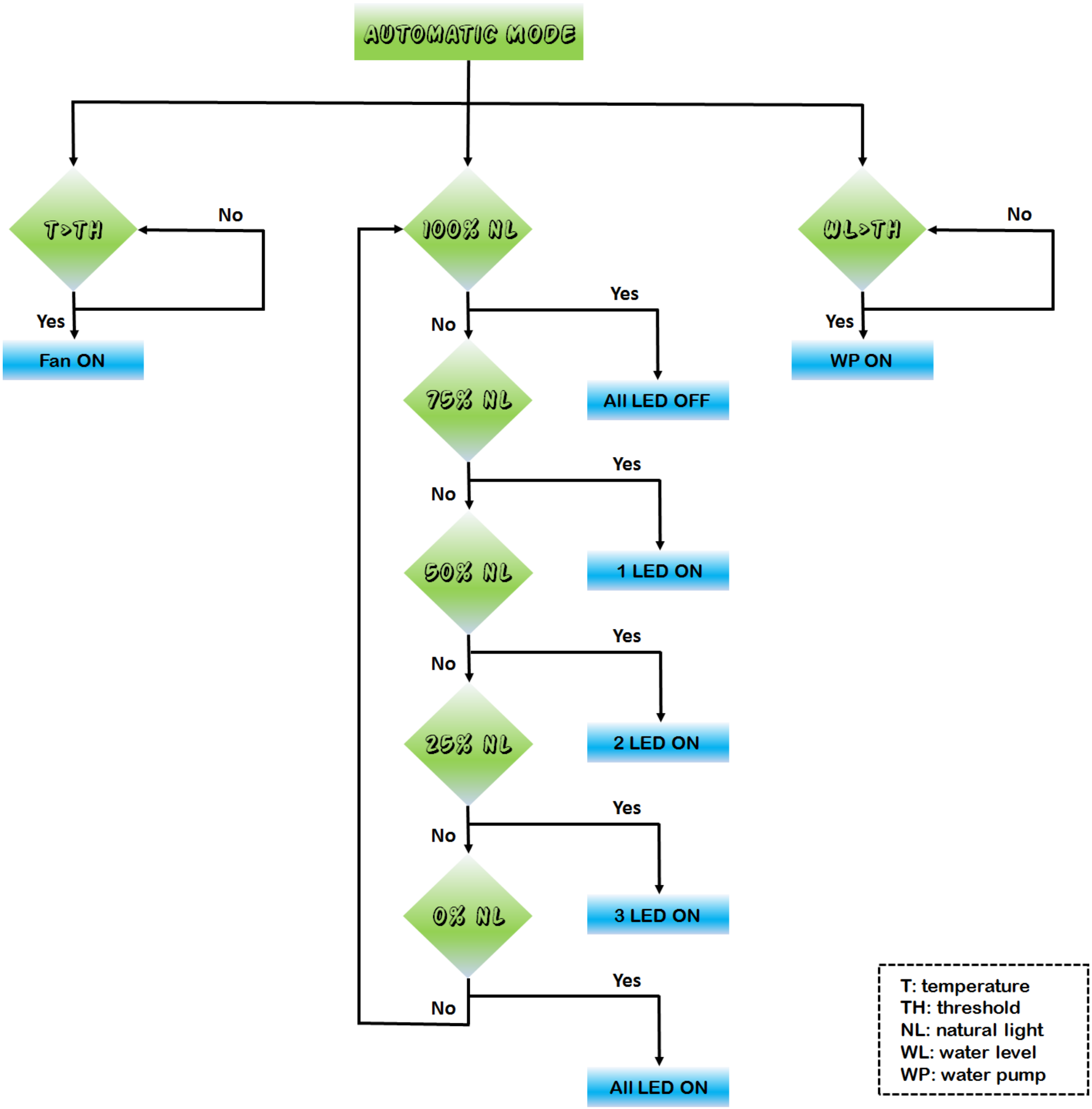


Figure 5.1.2. Automatic mode chart.

➢ Remote mode

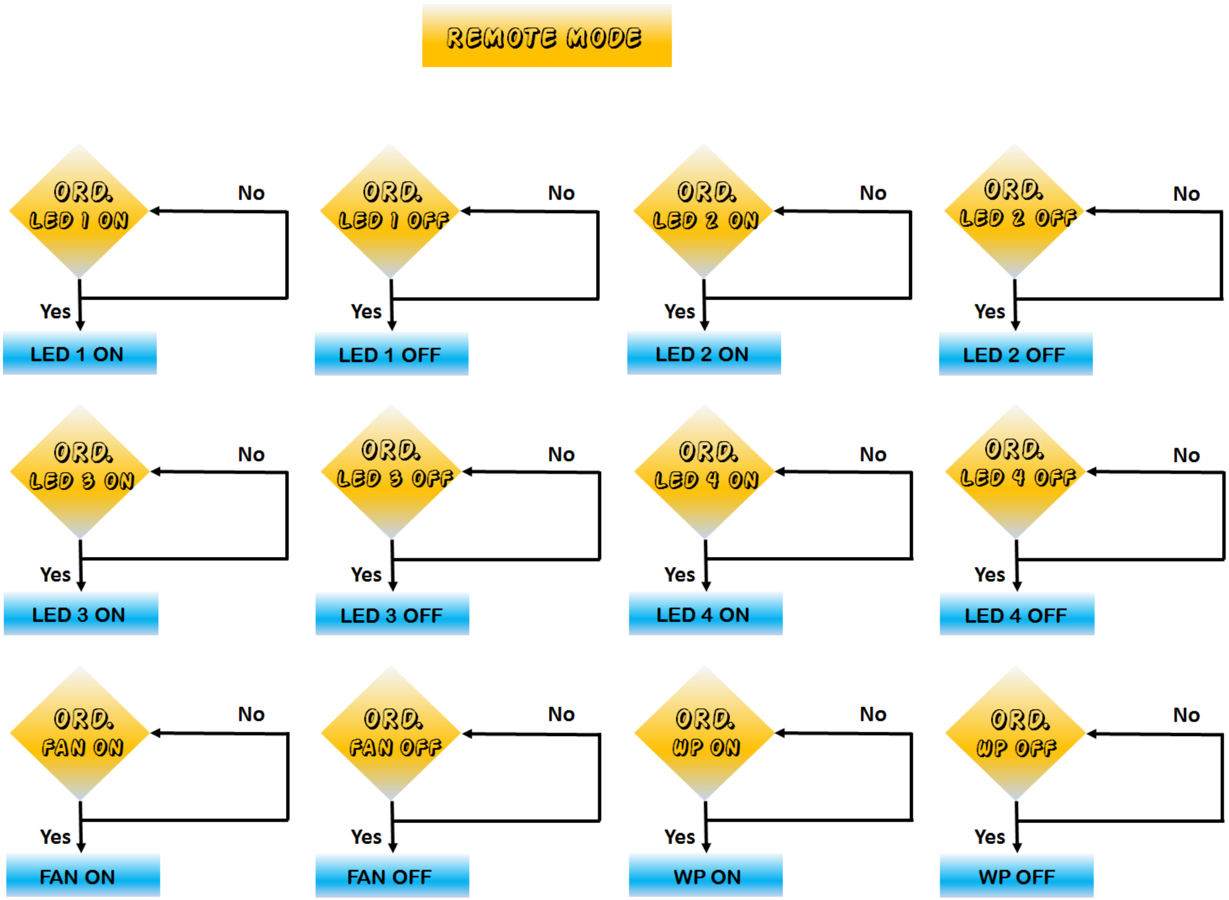


Figure 5.1.3. Remote mode chart.

- **Alarm mode**

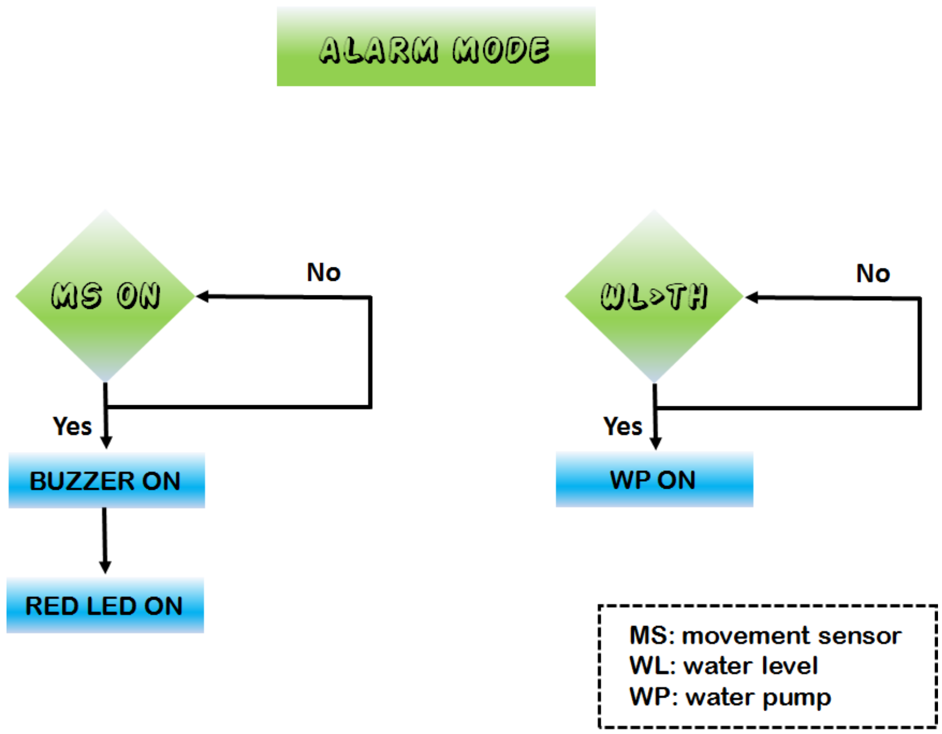


Figure 5.1.4. Alarm mode chart.

5.2. Arduino programming

As a global overview of Arduino programming, it is divided, as established in the IDE code development, in two main parts: *setup* and *loop* functions. The first is the function that is executed only the first time that application runs, instead the second one is executed as a loop, continuously.

For this application additional functions are included to segment and make the program more efficient. There is a function for each mode of function that includes the necessary control loops.

At the beginning of the Arduino code all the components are delimited: type, the pin to which is associated and the operation mode. In addition, it is also declared the global variables and the libraries which will be used in the whole code.

```
#include <Wire.h>
#include <LCD.h>
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>
LiquidCrystal_I2C lcd(0x27,2,1,0,4,5,6,7);
SoftwareSerial BT(10,11); //Tx and Rx pins for BT communication
const int temp_sensor = 0;  //pin A0 (temperature sensor)
const int fan = 22;  //pin D2 (fan)
float temp;  //temperature value
int threshold = 21;  //temperature threshold
const int LDRsensor = 1;  //pin A1 (lighting sensor)
const int LED1 = 6;  //pin D6 (LED 1)
const int LED2 = 7;  //pin D7 (LED 2)
const int LED3 = 8;  //pin D8 (LED 3)
const int LED4 = 9;  //pin D9 (LED 4)
int LDRvalue;  //natural light value
const int WL_sensor = 15;  //pin A15 (water level sensor)
const int Wpump = 13;  //pin D13 (water pump)
float water_level;  //water level value
const int mov_sensor = 3;  //pin D3 (movement sensor)
const int LEDalrm = 4;  //pin D4 (alarm LED)
const int buzzer = 5;  //pin D5 (buzzer)
int mov_value;  //movement value (true or false)
char state; //data sent from App
char mode; //mode selected according to "state" value
```

```
void setup() {
lcd.begin (16,2);
lcd.setBacklightPin(3,POSITIVE);
lcd.setBacklight(HIGH);
lcd.setCursor(0,0);
lcd.print("TFG");
lcd.setCursor(0,1);
lcd.print("Anna Merino");
delay(4000);
lcd.clear();
pinMode(temp_sensor, INPUT);  //temperature sensor Mode
pinMode(fan, OUTPUT) ;  //fan Mode
pinMode(LDRsensor, INPUT);  //lighting sensor Mode
pinMode(LED1, OUTPUT);  //LED1 Mode
pinMode(LED2, OUTPUT);  //LED2 Mode
pinMode(LED3, OUTPUT);  //LED3 Mode
pinMode(LED4, OUTPUT);  //LED4 Mode
pinMode(WL_sensor, INPUT) ;  //water level sensor Mode
pinMode(Wpump, OUTPUT);  //water pump Mode
pinMode(mov_sensor, INPUT);  //movement sensor Mode
pinMode(LEDalrm, OUTPUT);  //alarm LED Mode
pinMode(buzzer, OUTPUT);  //buzzer Mode
BT.begin(9600); //set data rate in bits per second (baud) for data transmission
}
```

Then, application will wait until the order arrives from the mobile application indicating which mode is going to be executed. This is included in the *loop* function, the part of the code that is continuously executed to change the mode in real time at the user's choice.

Letters are used to send the command that user select to Arduino board.

```
void loop() {
  if(BT.available()>0)
  {
state = BT.read(); //transfer data sent by App to a local variable
  }
if (state == 'Y')
  {
    mode = 'A';
  }
  else
  if (state == 'Z')
  {
     mode = 'R';
  }
  else
  if (state == 'X')
  {
     mode = 'D';
  }

  if (mode == 'A')
  {
    automaticmode();
    }
    else
    if (mode == 'R')
    {
      remotemode();
      }
      else
    if (mode == 'D')
    {
      alarmmode();
      }
}
```

If Arduino receives a “Y”, it will be use an internal variable called “mode”, the value of which will be “A” and then the code will execute the automatic mode function. If this mode is in execution the house will self-regulate following the parameters fixed by Arduino code. Depending on the natural light perceived a determined quantity of LED will be turned on, depending on the ambient temperature the fan will be on or off and depending on the water level of the pool the water pump will be on or off.

```
if (mode == 'A')
{
automaticmode();

       . . .

void automaticmode()
{
LDRvalue = analogRead(LDRsensor);  //data of natural light transmission to a local variable
water_level = analogRead(WL_sensor);  //data of water level sensor transmission to a local variable
temp = analogRead(temp_sensor);  //data of temperature sensor transmission to a local variable
temp = temp*0.4883; //adjustment of temperature value

       . . .

if (water_level > 100)  //water level control
{
digitalWrite(Wpump, HIGH);
}
else
{
digitalWrite(Wpump, LOW);
}

if ((LDRvalue < 1023) & (LDRvalue >= 822)) //control il·luminació
{
digitalWrite(LED1, LOW);
digitalWrite(LED2, LOW);
digitalWrite(LED3, LOW);
digitalWrite(LED4, LOW);
}
else if ((LDRvalue < 821)& (LDRvalue >= 617))

       . . .

if (temp >= threshold)  //temperature control
{
digitalWrite(fan, HIGH);
}
else if (temp < threshold)
{
digitalWrite(fan, LOW);
}

       . . .
```

If Arduino receives an "X" the internal variable value will be "R" and code will execute remote mode function. In this mode the board will wait until it receives a new order from the application. The possibilities for user to command the house are the following:

- ✓ Light on the 4 LED separately.
- ✓ Light off the 4 LED separately.
- ✓ Light on the 4 LED at once.
- ✓ Light off the 4 LED at once.
- ✓ Turn on the fan.
- ✓ Turn off the fan.
- ✓ Turn on the water pump.
- ✓ Turn off the water pump.

```
void remotemode()
{
digitalWrite(LEDalrm, LOW);
digitalWrite(buzzer, LOW);

  if(BT.available()>0)
  {
      state = BT.read();
  }

  if (state == 'D')
  {
    digitalWrite(LED1, LOW);
  }
  else
  if (state == 'C')
  {
     digitalWrite(LED1, HIGH);

        . . .
```

Finally, if it receives an "Z" the internal value will be "D" and code will execute alarm mode function. In this mode the buzzer will be activated together with a blinking red LED when movement sensor perceives movement around the house and the water pump will be activated when there is a risk of water overflow in the pool. This is a mode designed expressly for when the user is absent and want to keep the house under control: without thefts or water overflows that may bring undesired consequences.

```
void alarmmode()
{
water_level = analogRead(WL_sensor);  //data of water level sensor transmission to a local variable
if (digitalRead(mov_sensor)) //evaluate movement captured
{
digitalWrite(LEDalrm, HIGH);
digitalWrite(buzzer, HIGH);
}
else
{
digitalWrite(LEDalrm, LOW);
digitalWrite(buzzer, LOW);
}
if (water_level > 100)  //water level control
{
digitalWrite(Wpump, HIGH);
}
else
{
digitalWrite(Wpump, LOW);
}
  }
```

5.3. Mobile application programming

As already explained in previous sections, the mobile application has the power to choose between the three modes of operation and data is sent to the board using Bluetooth.

Figure 5.3.1. Mode selection screenshot.

In case of choosing remote mode, user can control all variables from mobile:

Pressing "ON" or "OFF" buttons of each section can light LED 1,2,3 and 4 separately. Pressing "All ON" or "All OFF" buttons can light all LED at once.

User can see if any LED is on or off in the interface of the application using two visual methods: will be shown an image of a light bulb on or off and the state written where the image and the label corresponding to each of them is located. The same will happen in the section of all LED together.

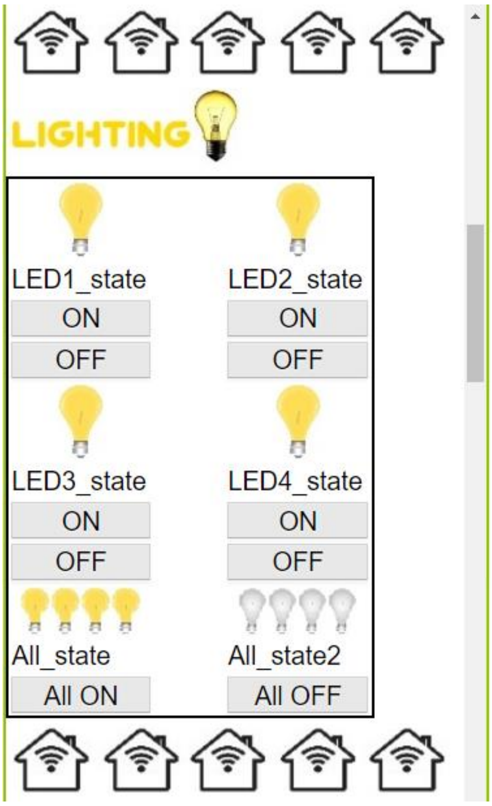


Figure 5.3.2. Remote mode screenshot - lighting.

For temperature control, user can press "Activate" button to turn on the fan and "Deactivate" to turn it off.

The fan image will be green in case the fan is activated and brown otherwise. The label placed near the image will show written the state.

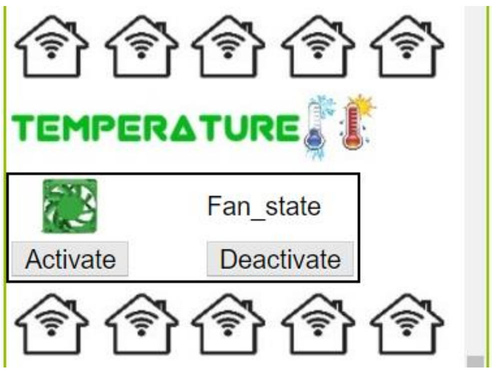


Figure 5.3.3. Remote mode screenshot – temperature.

For water level control, user can press “Activate” button to turn on the water pump and “Deactivate” to turn it off.

The water pump image will be blue in case the fan is activated and white otherwise. The label placed near the image will show written the state too.

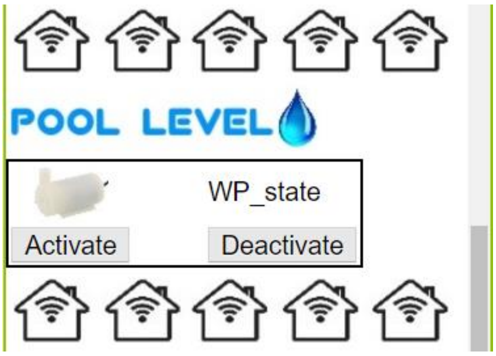
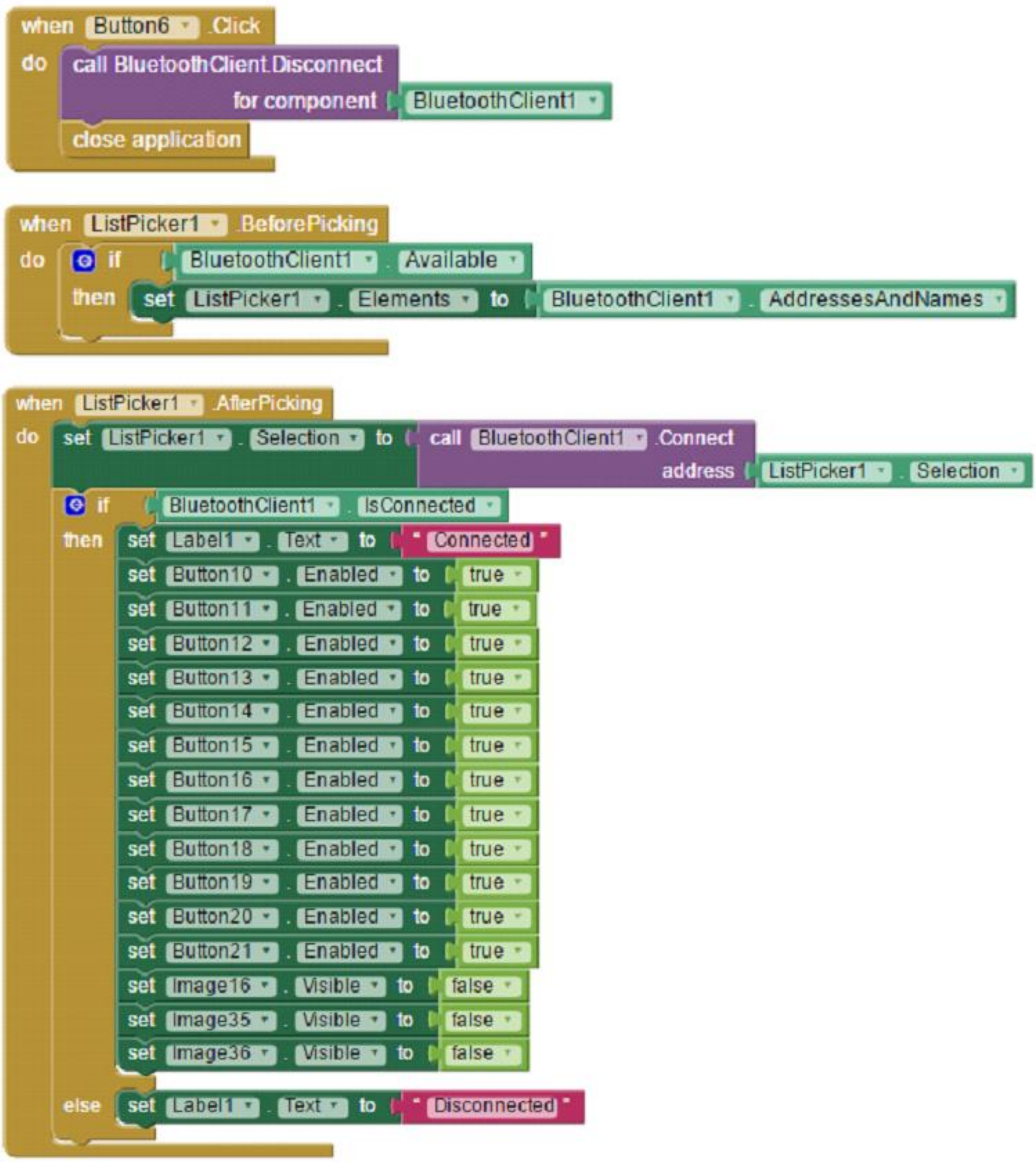


Figure 5.3.4. Remote mode screenshot – pool level.

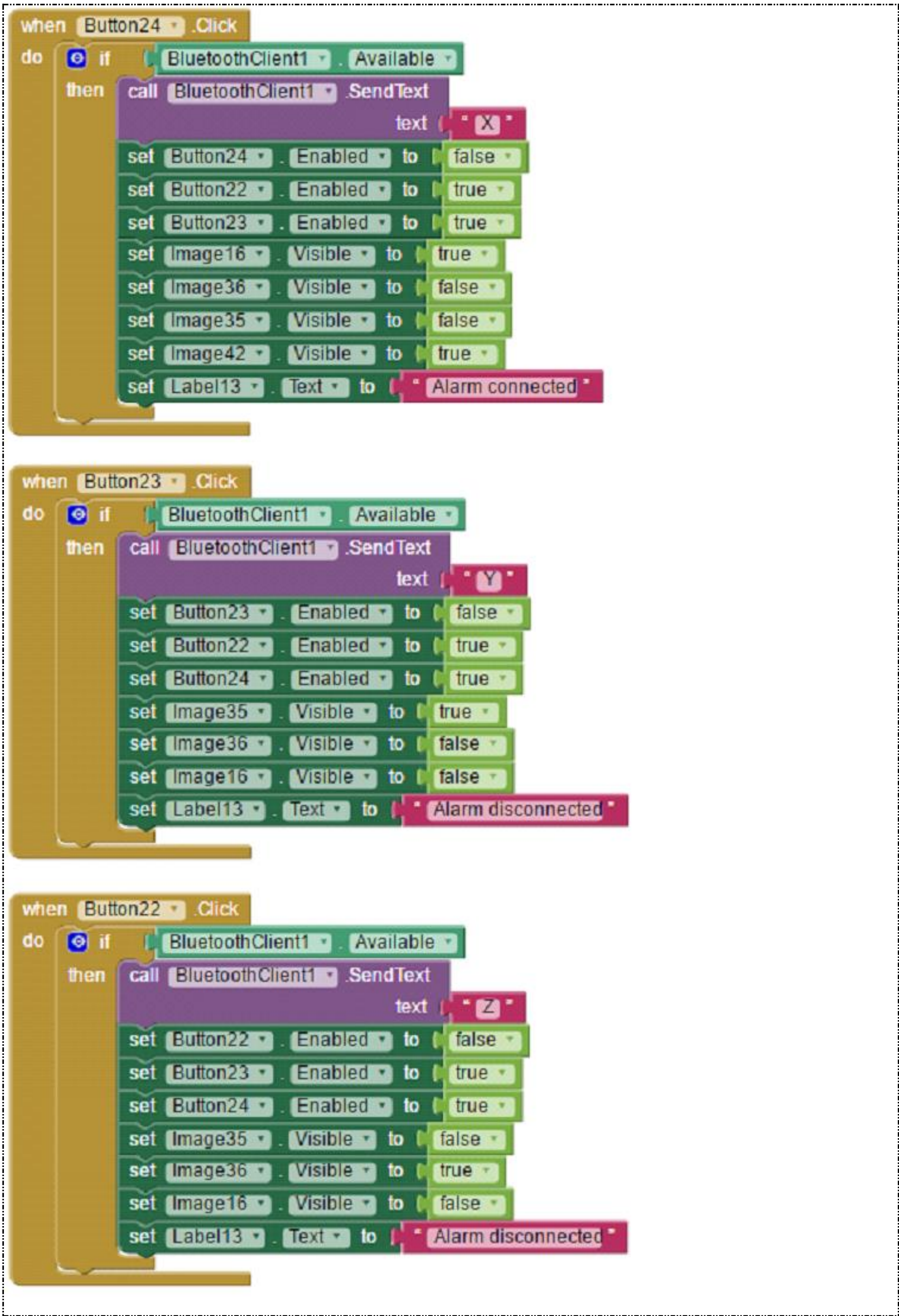
In case of alarm mode operation, the user only can see written if alarm is connected or not in the following interface:

Figure 5.3.5. Alarm mode screenshot.

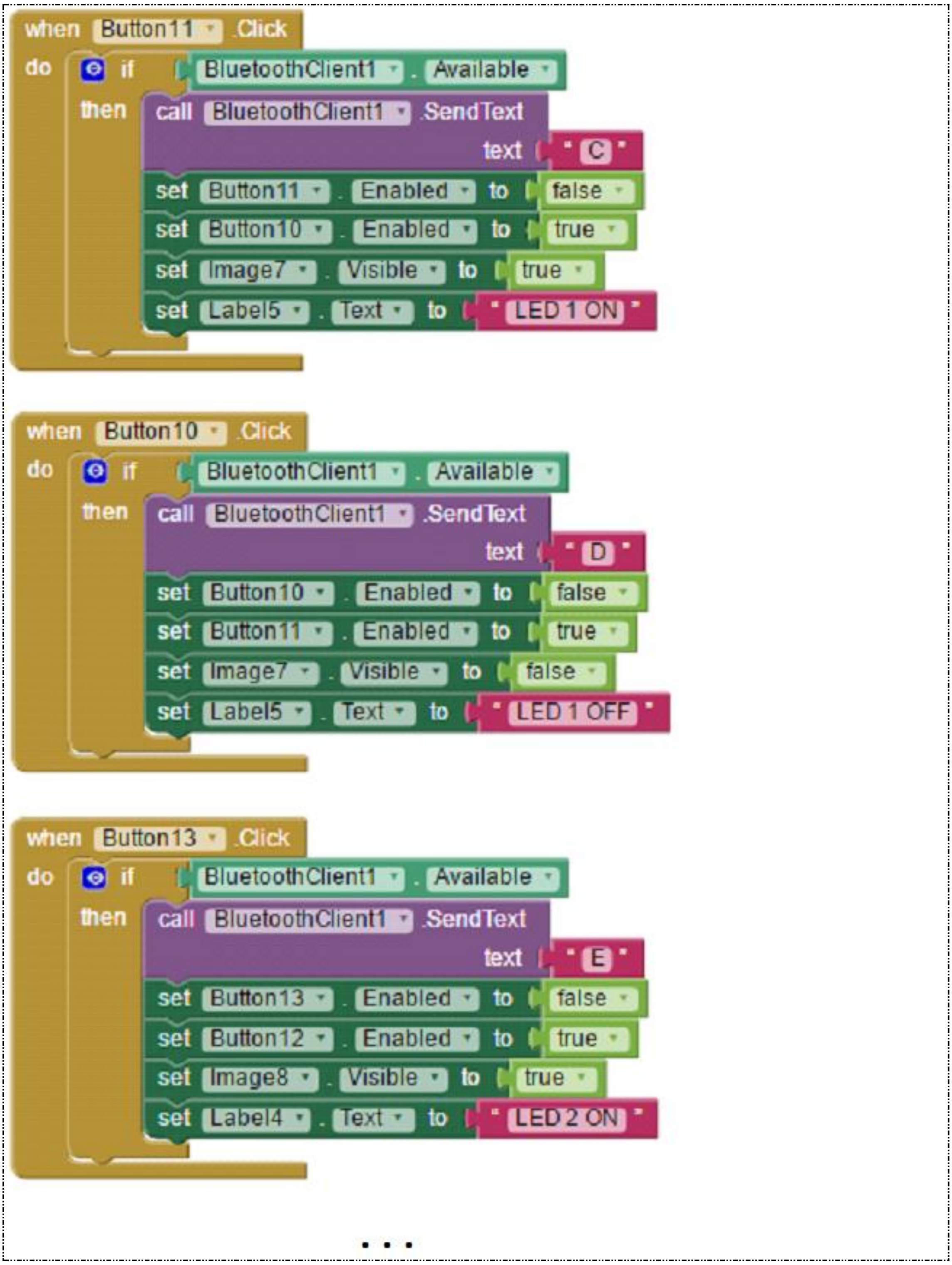
Mobile application is programmed with AppInventor software. It is designed to connect via Bluetooth with the Arduino that controls the house, is a specific App for a specific user.



Then user must choose between the three possibilities of operation modes.


when Button24 .Click
do if BluetoothClient1 . Available
then call BluetoothClient1 .SendText
text " X "
set Button24 . Enabled to false
set Button22 . Enabled to true
set Button23 . Enabled to true
set Image16 . Visible to true
set Image36 . Visible to false
set Image35 . Visible to false
set Image42 . Visible to true
set Label13 . Text to " Alarm connected "
when Button23 .Click
do if BluetoothClient1 . Available
then call BluetoothClient1 .SendText
text " Y "
set Button23 . Enabled to false
set Button22 . Enabled to true
set Button24 . Enabled to true
set Image35 . Visible to true
set Image36 . Visible to false
set Image16 . Visible to false
set Label13 . Text to " Alarm disconnected "
when Button22 .Click
do if BluetoothClient1 . Available
then call BluetoothClient1 .SendText
text " Z "
set Button22 . Enabled to false
set Button23 . Enabled to true
set Button24 . Enabled to true
set Image35 . Visible to false
set Image36 . Visible to true
set Image16 . Visible to false
set Label13 . Text to " Alarm disconnected "

Once operation mode is selected, if the one chosen is remote, user will be able to control devices as desired using the application buttons.



The can change operation mode whenever wanted.

The application programmed for this purpose uploaded to the mobile can be seen in the following image:

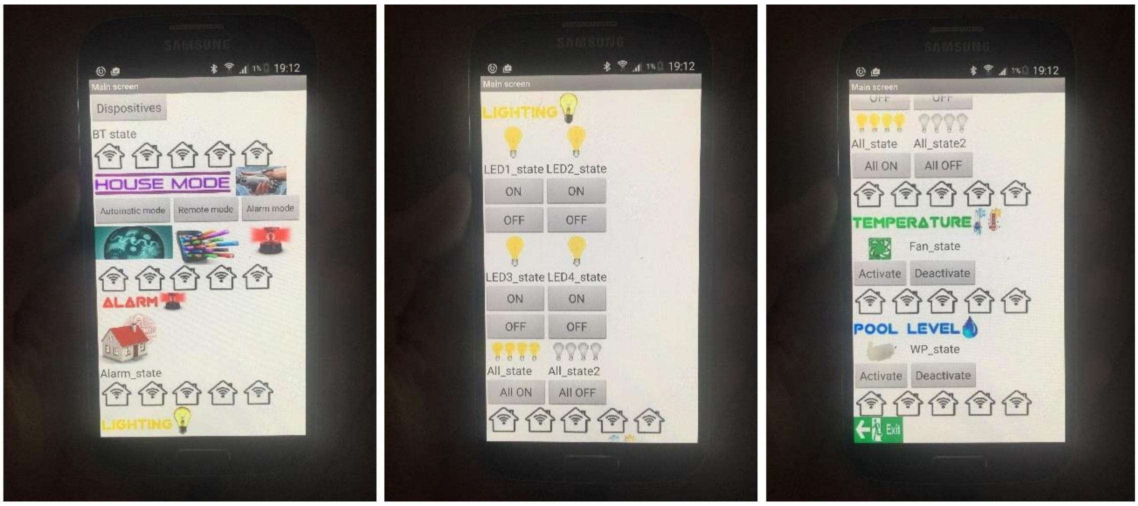


Figure 5.3.6. Mobile application visualization.

6. Budget

This chapter presents the first cost of the project, which is the cost of the prototype, and the cost of the application in mass production for sale to the public.

6.1. Prototype cost

The following table shows the cost of the components, both electronic and mechanical, necessary to successfully develop this application.

Table 6.1. Electronic and mechanical costs.

Product	Price/unit	Units	Total
Arduino Mega 2560	36,18 €	1	36,18 €
Bluetooth module HC-05	5,36 €	1	5,36 €
Display LCD 16x2	4,36 €	1	4,36 €
Temperature sensor LM35	1,85 €	1	1,85 €
Fan 5V	4,31 €	1	4,31 €
NPN transistor	0,45 €	1	0,45 €
LDR sensor	1,75 €	1	1,75 €
LED	0,42 €	5	2,10 €
PIR sensor	2,96 €	1	2,96 €
Buzzer	3,49 €	1	3,49 €
Resistor	0,04 €	7	0,28 €
Protoboard	18,51 €	1	18,51 €
AppInventor software	0,00 €	1	0,00 €
Android mobile phone	169,00 €	1	169,00 €
Wire roll	4,92 €	2	9,84 €
Welder	17,50 €	1	17,50 €
Tin roll	4,60 €	1	4,60 €
TOTAL			**282,54 €**

The cost in working hours to obtain a functional application is shown in the following table.

Table 6.2. Labour costs.

Concept	Price/hour	Hours	Total
Viability study	15,00 €	60	900,00 €
Electronic design	15,00 €	100	1.500,00 €
Software programming	15,00 €	150	2.250,00 €
Mounting of mock-up	15,00 €	12	180,00 €
Circuit welding	15,00 €	40	600,00 €
Testing and debugging	15,00 €	180	2.700,00 €
Documentation	15,00 €	150	2.250,00 €
TOTAL		**692 h**	**10.380,00 €**

Adding the costs of the previous tables, it can be obtained the cost of the entire application.

Table 6.3. Total costs.

Concept	Price
Electronic and mechanical costs	282,54 €
Labour costs	10.380,00 €
TOTAL	**10.662,54 €**

6.2. Mass production cost

This project could be commercialized as a learning tool to automatic and electronics students. In this section the cost per model in mass production is calculated.

To obtain the resultant cost, the following parameters must be taken in account:

- Buying the components in big batches, can be obtained a considerable discount. In this case, for the components used, **on average it can be discounted 20%.**
- In order to test the success that can have this model, a considerable number of products should be produced. So, it is decided to **produce 500 units.**
- To amortize the expenses and obtain benefit, each product will have a charge. In this case the **profit will be 15%.**

With above data, and removing the cost of mobile phone, because it is not going to be included in the pack, protoboard, because it is to perform tests and welding, the cost for components is as follows.

Table 6.4. Component costs in mass production.

Product	Price/unit	Units	Discount	Total
Arduino Mega 2560	36,18 €	1	20,00%	28,94 €
Bluetooth module HC-05	5,36 €	1	20,00%	4,29 €
Display LCD 16x2	4,36 €	1	20,00%	3,49 €
Temperature sensor LM35	1,85 €	1	20,00%	1,48 €
Fan 5V	4,31 €	1	20,00%	3,45 €
NPN transistor	0,45 €	1	20,00%	0,36 €
LDR sensor	1,75 €	1	20,00%	1,40 €
LED	0,42 €	5	20,00%	1,68 €
PIR sensor	2,96 €	1	20,00%	2,37 €
Buzzer	3,49 €	1	20,00%	2,79 €
Resistor	0,04 €	7	20,00%	0,22 €
AppInventor software	0,00 €	1	20,00%	0,00 €
Wire roll	4,92 €	2	20,00%	7,87 €
Tin roll	4,60 €	1	20,00%	3,68 €
TOTAL		**62,02 €**		

In mass production the labour cost will be lower for sure and the tasks that only have to be done once to get the resulting model can be skipped in these calculations.

The tasks that must be executed in this case with its associated cost are the following.

Table 6.5. Labour costs in mass production.

Concept	Price/hour	Hours	Total
Mounting of mock-up	15,00 €	1,5	22,50 €
Circuit welding	15,00 €	3	45,00 €
TOTAL		**52 h**	**67,50 €**

To finish, adding the VAT and profit costs, the final cost per product, the RRP (*Recommended Retail Price*) is shown below.

Table 6.6. Recommended Retail Price of home automation model.

Concept	Price
Component cost	62,02 €
Labour cost	67,50 €
Profit (15%)	19,43 €
VAT(21%)	27,20 €
Price/unit	**176,15 €**
Total price (500 units)	**88.073,60 €**

7. Conclusion

As it can be seen in the report´s development, all the objectives exposed in point 1.3 have been accomplished. It has not been an easy project and it required many hours of research to match expectations.

This thesis is based on what has been learned during the degree, expanding the knowledge in different areas to obtain a final project where three main electronic parts meet; electronic design (hardware), programming (software) and communication between devices.

The fact of having chosen home automation as a subject to work on has been fulfilling because it is an issue which is currently in full expansion and has a promising future. This technology is in constant expansion and its scope is growing to cover more important areas like security, accessibility and user´s comfort.

In addition, there is another technology that has been developed, which is currently highly used and that is mobile applications. Even though there are many platforms that allow users to create an application, the handicap has been creating an application capable to communicate with other devices and also making it exclusive to remotely control them. Personally, it has been the very first time that I created a mobile application and the hardest thing to complete the project was to make it work as desired. It has also been the most satisfying part.

As a summary, I have dealt with important parts of the degree I studied, using the knowledge acquired and increasing it, obtaining the know-how to get myself out in the professional market.

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