Home Automation through Facial Recognition

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Abstract

In this paper, the full development of the automation project will be shown, covering details such as objectives, results and personal experiences. The purpose of creating this project is to automate home tasks, which is achieved by using Arduino and Raspberry Pi microcontrollers that would detect users through facial recognition and adjust preferences depending on the user and time. This document will be divided in four sections: introduction, development, results and conclusions.

Keywords: home, automation, facial, recognition, Arduino, Raspberry, web, service

1 Introduction

In this section, the initial phases of the project will be explained. This includes the reason for creating this project, its current objectives, and a theoretical framework of the hardware and software used to create the project.

1.1 Reason for Creation of the Project

Nowadays, new technology is developed constantly and at extremely fast rates. The technological evolution has allowed men to perform tasks in easier, faster and more efficient ways. Contemporary technology is so advanced that it even allows men to perform tasks with little to no human supervision at all. Automation of processes and tasks is becoming more and more common as time passes by.
The reason for creating this project is to introduce this automation system into people's home, allowing users to turn on and off home appliances without physically manipulating the appliances. Furthermore, this automation process will handle different users and settings, which will be explained thoroughly in the next subsection. This ambitious project will introduce automation into our daily lives and will serve as an introduction to more complex and useful home automation projects.

1.2 Objectives

1.2.1 General Objectives

The general objective of this project is to develop a product that achieves home automation. The product developed in this project will control home appliances automatically, creating an automated and effortless experience for its users. To be considered fully operational, the project must have the following characteristics:

- The product must be able to turn on and off home appliances, which will depend on the user and time of day.
- The product must have an edit mode, in which the users will be able to modify their current profiles which will indicate the home appliances that must be turned on or off.

1.2.2 Specific Objectives

The specific objectives of this project involve the phases in which the development of the product is established and the scope that the project will cover. The development of this project is divided in four main phases:

- First Phase: Modern facial recognition systems must be researched in order to select an appropriate system that fulfills the project's general objectives.
- Second Phase: Software that will be needed to recognize users with a camera must be implemented. This phase includes the development of additional software, such as

web services, and handling the user information and recognition. The last part of this phase is the system design, which will be achieved by designing both software and hardware interaction.

- Third Phase: Circuitry needed to test the system's functionality must be implemented. The built circuitry will serve to test the product with actual home appliances.
- Fourth Phase: Software and hardware components must be put together in order to create a prototype that will test the product's functionality. The result of this final phase must be an operational product that satisfies the general objectives stated in the previous subsection.

However, the time of development for the project is short, and therefore the scope for this project will be restricted. This means the prototype presented will have some restrictions and will cover all functionalities and/or objectives stablished in the previous subsections. The prototype will not include an actual home installation, but rather a small representation of this function. This will be achieved by simulating one room with one camera that runs facial recognition and that is capable of identifying four different users. Additionally, four different user profiles will be preloaded into the system. The system will control two light bulbs that will simulate the home appliances that are connected to the system. Each user profile will control differently each light bulb, depending on the user's settings.
Another restriction is that the prototype will not take into consideration the time of day, meaning user settings and preferences will not be affected by day of time.

1.3 Theoretical Framework

In this subsection, concepts regarding important hardware and software components will be briefly explained. The purpose of this subsection is to allow readers to understand the project and its components, including those readers that lack knowledge about software and hardware.

1.3.1 Raspberry Pi

The Raspberry Pi is a "low cost, credit-card sized computer", created by the Raspberry Pi Foundation, with capabilities of performing most desktop computer tasks. [1] The Raspberry Pi has the ability of receiving and transmitting data from and into the outside world, making the amount of possible Raspberry Pi projects endless.
In this project, the Raspberry Pi is used to recognize faces and control the flow of data through web services. Web services will be explained in this subsection later on.

1.3.2 Arduino

Arduino is "an open-source prototyping platform" based in both software and hardware components. [2] Hardware components include Arduino boards, which are able to detect inputs from the outside world and turn it into a signal to perform almost any type of task. Unlike the Raspberry Pi, the Arduino software components consist in its own integrated development environment, in which the user can instruct Arduino to perform tasks.
In this project, Arduino boards are used to control the home appliances. This is done by turning on and off circuits directly connected to both Arduino boards and physical appliances. Arduino boards also receive the user information by Bluetooth, a communication protocol which will be explained later on.

1.3.3 Web Services

A web service is a software system designed to support machine-to-machine interaction over a network. [3] This system has an interface that is described in a format that can be processed by machines. Web services allow machines to work on different languages and frameworks to communicate effectively.
In this project, the web service designed to work with the product is a RESTful web service, which uses HTTP methods explicitly. [4]

1.3.4 Bluetooth

Bluetooth is "a global wireless communication standard that connects devices together over a certain distance." Bluetooth uses waves to connect devices instead of connecting through cables. Communication is possible over short-range networks that use Bluetooth technology. [5]
In this project, Bluetooth is used to send user information from the Raspberry Pi to the Arduino boards, which later on will be processed to turn on or off the home appliances.

2 Development

In this section, the development regarding the functionalities of the project will be explained. This section will include interfaces, diagrams, circuitry schematics and a description of the project development

2.1 Project Development

2.1.1 Face Recognition

The first feature to be developed in the project was face detection with a normal camera. The first task that had to be completed was the investigation of face recognition technology. After investigating various options, the open source library OpenCV (Open Source Computer Vision) was chosen. The reason this library was chosen is because it is an open source library (meaning that anyone can use it) and because of its high reliability and general effectiveness. Tests were conducted with the camera, reinforcing the decision of choosing OpenCV over other facial recognition libraries. Finishing this task, the first phase of the project was concluded. This was previously stated in the Specific Objectives subsection.

2.1.2 Software and System Development

After choosing OpenCV as the face recognition library for this project, the next step was to implement it, develop additional software and design the product's system. The first task to be done in the second phase of this project was the design of the product's system. Since most of the necessary hardware components were owned at the time, the system was developed quickly. The design of the system will be presented later on in the Block Diagram subsection.
The next task on the to-do list was the implementation of the OpenCV library. The Raspberry Pi was configured to work with the face recognition library. Afterwards, a camera was connected to the Raspberry Pi which had the library. Tests were performed on the camera and was completely configured afterwards.
The last task of the second phase was the development of additional software. Web services will be vital for the communication between the client and server Raspberry Pi. A short investigation regarding different types of web services was conducted, and RESTful web service was chosen because of its direct HTTP methods and stateless transfers. The web service to transfer user information between the client and server Raspberry Pi was developed and implemented. With this, the second phase of the project was completed.

2.1.3 Circuitry Development

The last task before hardware and software integration was the development of the system's circuitry. Building the circuitry was no easy task, as many other additional steps had to be taken to complete it.
First, a basic communication circuit between the Arduino board and Raspberry Pi was taken from Timothy Maloney's "Modern Industrial Electronics" book. [6] After choosing the circuit design that would fit the needs of the system, a circuit diagram was designed in EAGLE, an electronic design application with a diagram editor. The circuit diagram designed was based on the design taken from Maloney's "Modern Industrial Electronics". Soon after completing this step, the circuit was built. This was done by printing the circuit diagram on a special paper, and ironing the printed design on a copper board. A special socket was built into the circuit to allow serial connectivity between the circuit and the Arduino board. With this step done, the circuit was tested and, therefore, the third phase of the project was completed.

2.2 User Interface Diagrams

Users will be able to edit their profiles and settings by going into the product's web page. This web page will have interfaces that will allow users to modify their profiles, settings, and create new ones. In this subsection, the mock-up and final version of each user interface will be shown. The mock-up for the interface to create new user is shown in Figure 1:

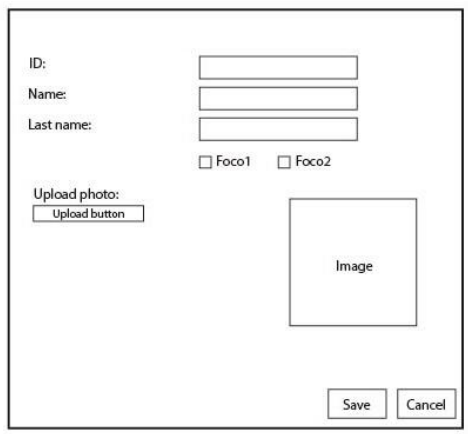

Figure 1: Interface mock-up – new profile.

This interface is straight-forward: the user completes the first name and last name. The ID can be filled with an integer number. Then, the user can upload a picture of itself by using the upload button. When all the profile information has been filled out, the user can press save to create the new profile or cancel to stop the creation of a new profile. The final version of this interface can be seen in Figure 2:

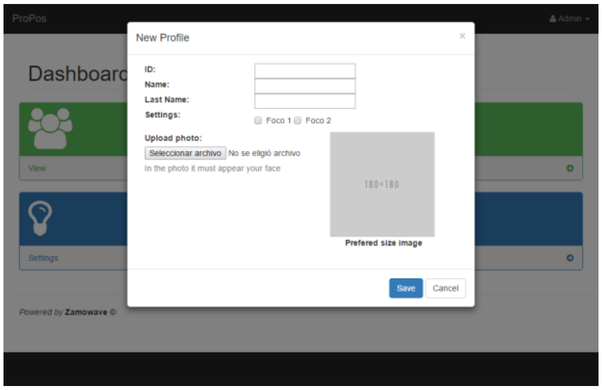

Figure 2: Interface final version – new profile.

After creating the new profile, the user will be able to choose from various options: to view profiles or to review lights (or home appliances). This will be done in an index user interface. The mock-up for the index user interface is shown in Figure 3333:

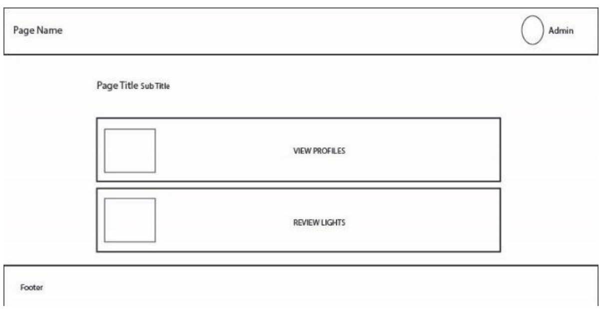

Figure 3: Interface mock-up – index.

In this interface, the user can press one of two buttons to navigate in the control panel. The first button allows the user to view and modify profiles, while the second button modifies appliances settings. The final version of this interface can be seen in Figure 4:

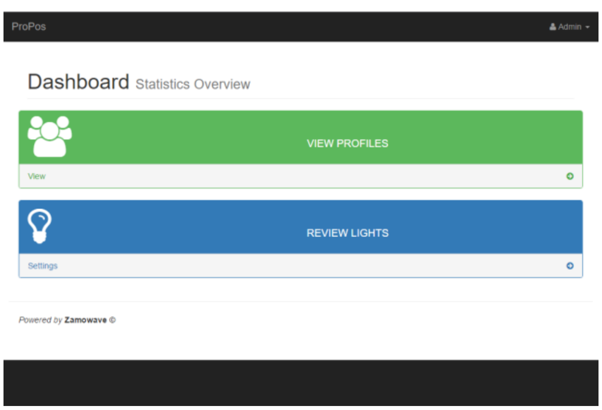

Figure 4: Interface final version – index.

If the user chooses to view profiles, it will be sent into a profiles interface. In this interface, all saved profiles will be listed, along with its details, such as name, last name, and ID. Both profiles mock-up and final version of this interface are shown in Figure 5 and Figure 6:

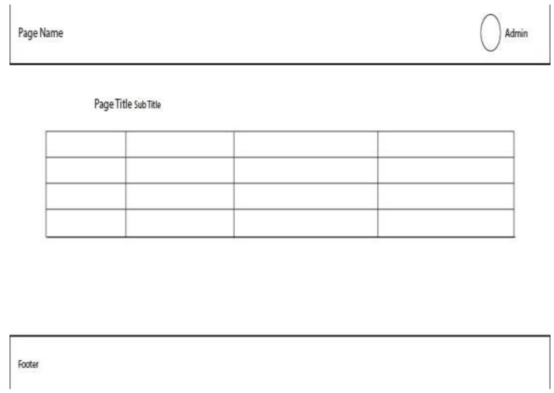

Figure 5: Interface mock-up – profiles.

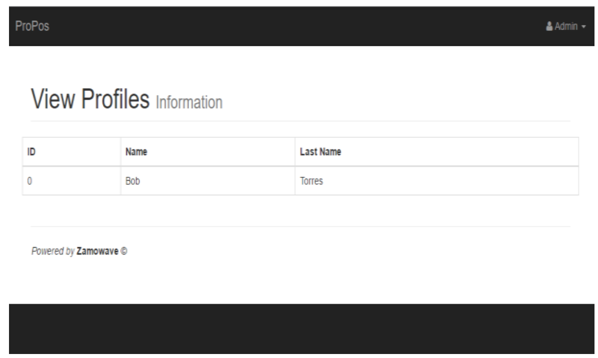

Figure 6: Interface final version – profiles.

However, if the user decides to review lights instead, it will be sent to a settings interface. The mock-up for the interface that allows users to modify settings is shown in Figure 7:

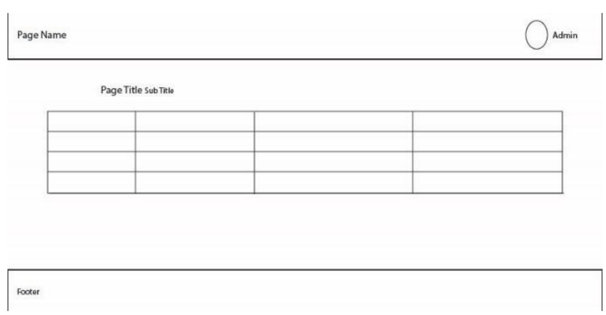

Figure 7: Interface mock-up – settings.

A table listing all users and their appliances settings will appear in this interface. Users can toggle between different appliances to edit current settings. The final version of this interface can be seen in Figure 8:

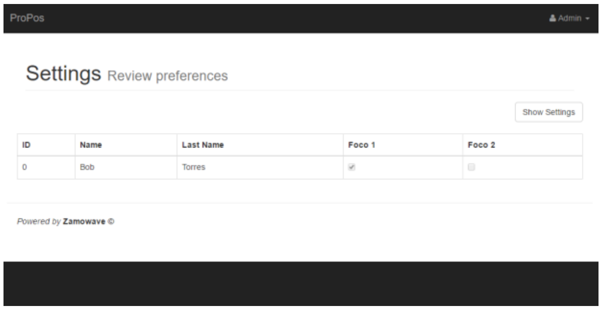

Figure 8: Interface final version – settings.

2.3 Class Diagrams

In this subsection, the diagram regarding the classes used will be shown. The project counts with five different classes, one for user profiles, one for the user, one for the user's resources, one for the controller, and one for the slave controller. The class diagrams can be observed in Figure 9:

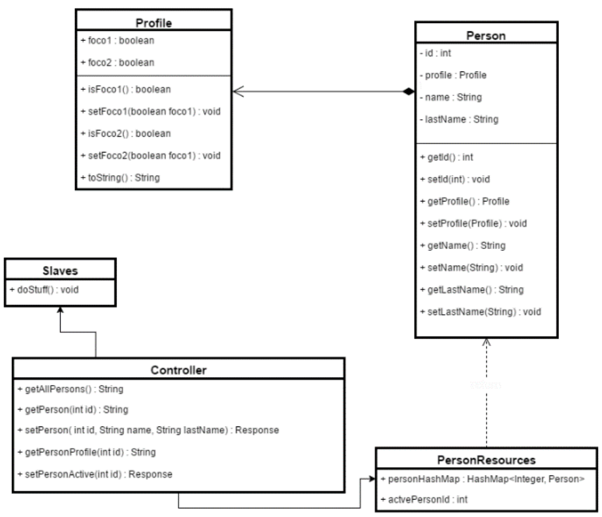

Figure 9: Class diagram – profile, user, resources, controller, and slave.

The user profile class has two Boolean variables named after each light bulb, along with Boolean checks and setter methods. The user class has variables for an ID, a profile, a name and last name, along with getter and setter methods. The resources class has a Hash Map variable which maps a user against a map value and an ID variable. The controller class has getter and setter methods used to control the light bulbs. The slave class has only one method, which tells the light bulbs to either turn on or off, depending on the information provided by the controller.

2.4 Sequence Diagrams

In this part, the sequence diagrams are shown. There are two sequence diagrams, one regarding the facial recognition system with the client Raspberry Pi and one regarding the serial communication between the server Raspberry Pi and the Arduino boards. The face recognition sequence diagram is shown in Figure 10:

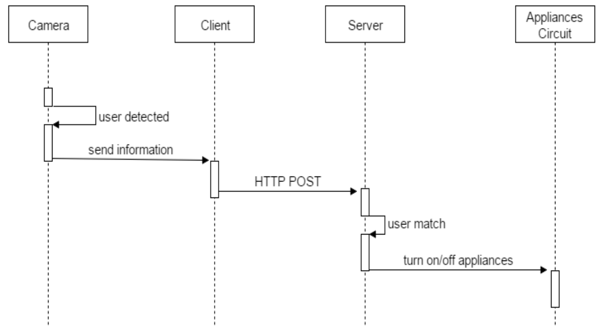

Figure 10: Sequence diagram – face recognition.

At first, the camera detects a user and sends this information to the client Raspberry Pi. Then, the client Raspberry Pi sends information to the server through a POST HTTP method. Once the server receives this information, it is processed and matched with an existing user. With a match, the server sends the information to the Arduino boards, and therefore, the appliances circuit. The circuitry sequence diagram is shown in Figure 11:

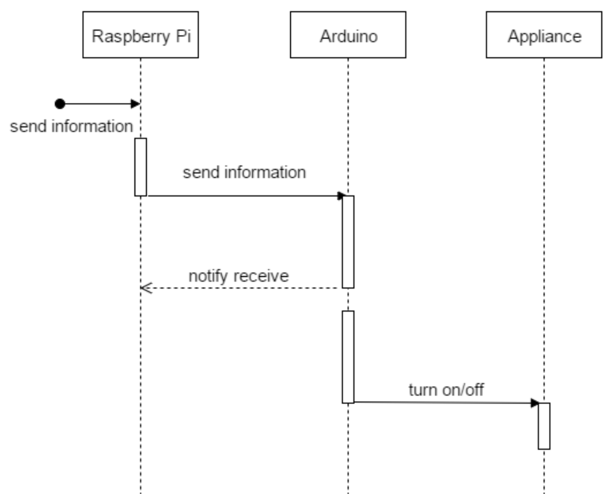

Figure 11: Sequence diagram – circuitry.

When the Raspberry Pi receives information, it sends it to the Arduino boards, which notifies the Raspberry Pi it has received the information successfully. After choosing which method to execute, the Arduino board instructs the appliance to either turn on or off, depending on the method chosen.

2.5 Deployment Diagram

The purpose of including a deployment diagram in this report is to aid the reader visualize the way the components are connected in the system. This diagram supports the block diagram, which can be seen in the next subsection. In this subsection, the deployment diagram of the project is shown.

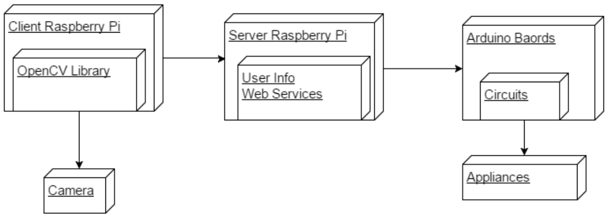

Figure 12: Deployment diagram.

2.6 Block Diagram

In this part, the design of the system will be shown. This block diagram represents the inputs, outputs and communication processes among the hardware and software components. The block diagram is shown in Figure 13:

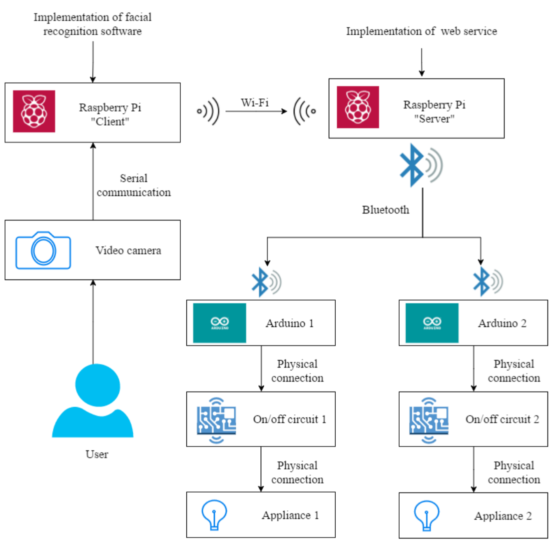

Figure 13: Block diagram – system design.

First, the user shows his face on the video camera that is connected to the client Raspberry Pi, which recognizes its face with the aid of the OpenCV library. This information is sent to the server Raspberry Pi through the designed RESTful web services. The server Raspberry Pi processes this information and sends the corresponding commands to the Arduino boards through the Bluetooth protocol. Each Arduino board receives the information and manipulates home appliances through the built circuits.

2.7 Circuitry Schematics

The printed circuit layout also be shown; however, the difference between layout and schematics is the representation. Circuit schematics are a representation of circuit connectivity. The circuit layout is the physical representation of the schematic. The circuit schematics is shown in Figure 14:

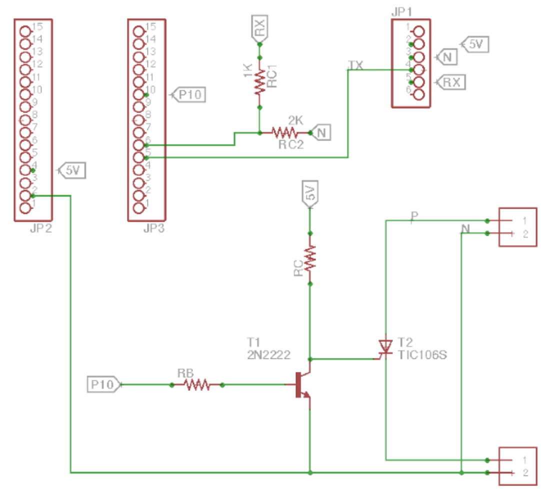

Figure 14: Circuit schematics.

The circuit layout is shown in Figure 15:

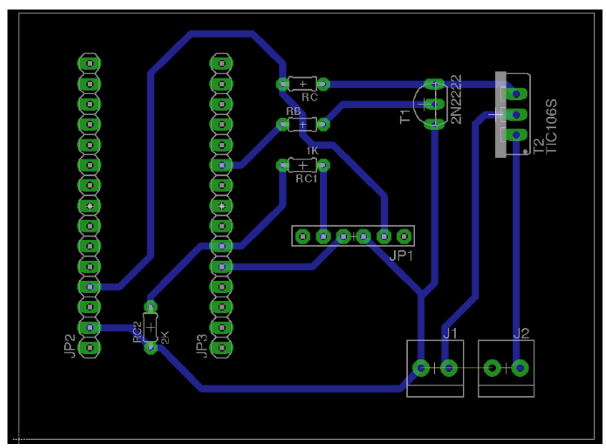

Figure 15: Circuit layout.

3 Results

In this section, the results of this project will be shown. This section includes encountered problems and cost of material.

3.1 Project Results

The results obtained from executing this project were the ones stated in the General Objectives subsection: a functional prototype that turns on and off home appliances and that has the capacity of editing user settings. The prototype is capable of recognizing faces from different users through its camera and turns on and off home appliances, depending of the user. Additionally, each user is able to edit his/her profile via the user interface in the web page. The result of the whole system is overall satisfactory and demonstrates the power of automation in a home environment.

3.2 Problems

Not many problems were encountered throughout the development of the project. However, the problems that were encountered will be listed in this section:

- Lack of knowledge in certain areas, especially in facial recognition.
- Erroneous implementation of the facial recognition library.
- Communication problems among Arduino boards and the Raspberry Pi.
- Building errors when building the circuitry needed for the project.

Most of these problems were solved with further investigation in the area.

3.3 Cost of the Project

The restriction on the project's scope was a relevant influence that ultimately affected the project's price. The creation of a prototype, rather than a real-scale model, significantly reduced the cost. Also, most of the components used were already owned by the development team, which decreased further the cost. Not taking into account the components that were previously owned, the cost of this project ranged between 30$ and 50$ USD. The components used in the project were:

- Two Raspberry Pi – 2B model.
- Two Arduino boards – Nano model.
- Two Bluetooth modules – 2HC05 model.
- Two Bluetooth modules – Mate Spark Fun model.
- One video camera – Logitech model.
- Two light bulbs – used to simulate appliances.
- Resistors, capacitors, wire, SCR, terminal block, transistors and connecting components.

4 Conclusions

In this section, the conclusions of each team member, lessons learned and acknowledgements will be shown.

4.1 Lessons Learned

Alejandro Arellano: I learned that, even though I'm not an expert neither in electronics, nor in software, I am perfectly capable of implementing an automation system in my house. Whether it is controlled by facial recognition, like in this project, or controlled by other means, like a mobile "app". I have the necessary skills to implement functional systems that can actually be useful for me and my family. I will definitely try to apply the concepts learned in this project to build a system for my house.

Yamil Elías: In this course I've learnt to use Web Services in a webpage with Java language. Also, because of this, I reinforced my knowledge in JavaScript, due it was used to communicate the web page with the Web Service. In electronics, I learnt what can be made with some electronical components, like making a dimming light and control a lot of voltage just with 5 Volts using different stages.

Jonathan Torres: In this project, I realized the importance of knowing both theory and practical applications of what we're taught every day in class. It wasn't until we started developing the project that I became aware of the power of IOT and what this will mean in the future. I became really interested in this powerful concept, the Internet of Things, and will I continue investigating to create better technological projects.

Arturo Zamora: I've always been fascinated with this kind of projects; in this occasion we had the opportunity to develop something including the machine vision technology. We use OpenCV in order to detect faces and based on that, load a profile for the current person. I've always wanted to experiment with OpenCV and now it was my opportunity. It was quite easy, because all the linear algebra operations were already implemented. The next thing to do is to investigate about types of security for communication among devices, that we could be implemented.

4.2 Conclusions

It wasn't until this semester that the developement team had the opportunity to experience the practical application of many programming concepts, such as web services, and wireless and serial communication. The real twist of this project was including basic control circuitry to create a technologically advanced product. The project is considered to be a real success because of the practical and theoretical knowledge put together. Also, the creation of this project gave the developement team a glimpse of how much can be done with knowledge and basic components and the sleeping potential that lays behind more complex components and concepts. Home automation is strictly tied to Internet of Things (IOT), a concept that has been gaining strength in the last few years.

“Simply put, this is the concept of basically connecting any device with an on and off switch to the Internet (and/or to each other). This includes everything from cellphones, coffee makers, washing machines, headphones, lamps, wearable devices and almost anything else you can think of. This also applies to components of machines, for example a jet engine of an airplane or the drill of an oil rig. As I mentioned, if it has an on and off switch then chances are it can be a part of the IOT. The analyst firm Gartner says that by 2020 there will be over 26 billion connected devices…” (Forbes, 2014)[7]

Technology has evolved a lot in the recent years, allowing people to do things that were thought as impossible some decades ago. With IOT becoming more popular and dominant in technological trends, as Information Technology Engineers, the developement team is aware of the possibilities, advantages and impact that technology can have in people’s lives. The prototype built is just a little demonstration of how powerful can IOT be, and how it must be exploited to reach the maximum potential to never settle with small things. To conclude with this project, there is lots of available technology out there ready to be used and create other technological products. Knowledge is powerful, and practical implementations are endless.

4.3 Acknowledgements

Even though the developement team spent many hours and days into creating this project, the result would never have been achieved without the help of individuals that guided us through the project. The team expresses its gratitude towards professor Enrique Sanchez and Jose Villareal, whom, even though they were not a part of the team, invested time and effort into guiding the steps and actions performed. Both professors were willing to help at any time and gave the team important points which ultimately resulted in a successful project.

5 References

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