HOME AUTOMATION FOR LIGHTING SYSTEM

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Orlindo Wagner Soares Pereira[1], Adriana da Silva Torres[2], Moisés de Matos Torres[3]

ABSTRACT

Automation and control techniques can be used in industrial and residential environments. The lighting system of a home can be controlled conventionally as well as electronically. The *treeway* circuit is a technique widely used in electrical installations that require the activation and disconnection of lamps in different positions in an environment. Prototyping platforms such as Arduino favor the control and interpretation of signals from other electronic devices, in addition to enabling the association with platforms for the creation of interactive graphic environments, such as *Processing*. *Processing*, in turn, performs image analysis and processing and generates information that can be saved in a text file. Both Arduino and *Processing* are open source platforms. Cloud *computing* tools, such as Dropbox, are useful for storing files on the network itself, so that they can be accessed and modified remotely through other computers, *tablets* and *smartphones*. Arduino, *Processing* and Dropbox are compatible with different types of computers, including small processors that operate on different architectures, such as the Raspberry pi family. By applying the concepts of control and automation of systems, instrumentation, *open source tools* and *cloud computing*, it was possible to build a control system for the lighting system of a residence in order to be an alternative for the rational consumption of electricity.

Keywords: Home automation. Treeway circuit. Arduino. Processing. Dropbox. Raspberry pi.

[1] Federal University of the Jequitinhonha and Mucuri Valleys
[2] Federal University of the Jequitinhonha and Mucuri Valleys
[3] Federal University of the Jequitinhonha and Mucuri Valleys

INTRODUCTION

Currently the control of systems has been the object of interest of companies, engineers and professionals who work in information management and process management. Some of these systems can be simplified and implemented within the scope of home automation. With some electronic prototyping tools on the market, it is possible to connect these systems to the world wide web: the internet.

The lighting system of a residence basically consists of the task of turning the lamps on and off. In most cases, the change of state is achieved by actuating an electromechanical switch. There are situations in which certain parts of the house need to be lit and others do not, and vice versa. From a technical point of view, would it be possible to build a control system that allows the user to activate the lamps locally and via the internet? What would be the implications for the conventional lighting system?

In order to answer the previous questions, Chapter 3 of this work sought to briefly present some tools and technologies that can be used for the development of a simplified system for turning on and off light bulbs in a home. In the part of materials and methods, it was sought to clarify the way the system works Finally, in the results and discussions part, analyses were made about the operation of the system, cost analysis of the main elements of the system.

OBJECTIVES

GENERAL OBJECTIVE

Development of a system capable of controlling the activation of lamps in a residence, in addition to evaluating the technical aspects involved, financial feasibility and evaluating the possibilities of improvement in the design of the system.

SPECIFIC OBJECTIVES

Build a system for turning on and off a home's light bulbs through electronic prototyping platforms, graphic programming, and "cloud" file storage tools. For the development of the project, the specific objectives are:

- Design, simulate and build circuits and actuators;
- Associate prototyping and programming platforms;
- Configure the control unit;
- Conduct a cost study of the implementation of the system.

STATE OF THE ART

In this section of the work, concepts, definitions and tools will be presented that, properly associated, can be used to create an *on-off* control system for the control of the turning on and off of lamps in a residence.

CONTROL AND AUTOMATION SYSTEMS

There are situations that motivate the implementation of an automation system. For example, when it is difficult to access a certain environment, whether due to physical conditions (risk of injury), chemical and biological risks. In these situations, it is interesting to program and command machines or devices to perform tasks that would previously be performed by people.

A purely automated process accomplishes the task, but does not evaluate it. This means that the system works only in the way it was designed and programmed. The system is inflexible to changes that may arise from the process or operation itself.

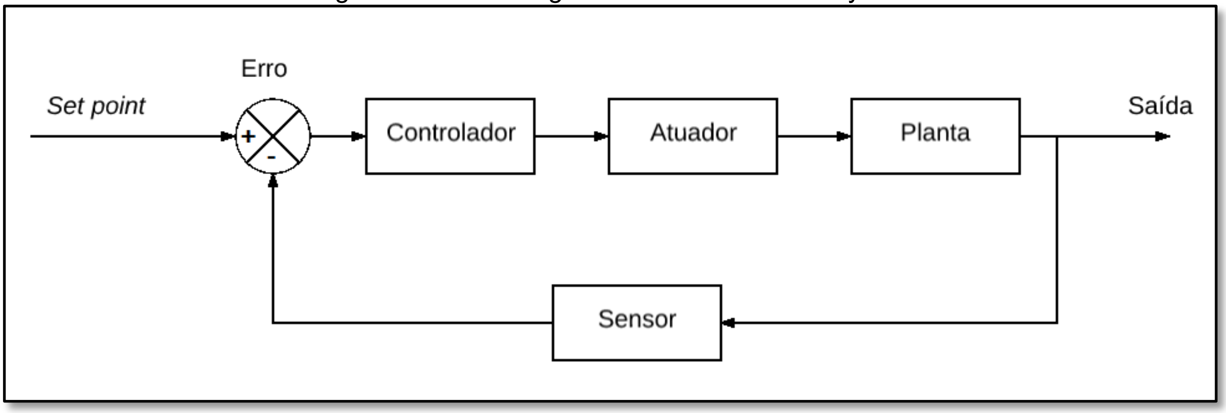
On the other hand, the controlled process needs a reference to carry out the operation. This reference, or *set point,* is obtained after a check (evaluation) at a given point in the system.

For the development of a control system, whatever it may be, it is important to be clear about what you want to control in the system. Another important issue is to define whether the system will be automatic, controlled or both alternately. For the system to be considered automatic and controlled, it is essential that it has the following elements: sensor, actuator and controller, which are defined as:

- ✓ The Sensor: component responsible for converting a physical quantity into variations of an electrical nature;
- ✓ Actuator: component responsible for performing actions capable of changing the state of the system;
- ✓ Controller: defines the mode of operation of the system through the execution of commands based on the processing of information.

Another way to relate these concepts is through the block diagram. Figure 1 presents a block diagram that allows us to understand the basic basis of operation of a feedback control system.

Figure 1 – Block diagram for a basic control system



Source: author's own production.

The arrows represent the passage of signals or information to the next component or process. According to OGATA (2010, p. 2), "Controlling means measuring the value of the controlled variable of the system and applying the control signal to the system to correct or limit deviations from the measured value from a desired value".

The block diagram in Figure 1 represents a closed-loop control system. If the control signal was independent, the output signal would be called open loop. In a control system project, it is important to evaluate which type of system is most suitable, especially evaluating the characteristics that offer the best advantages:

> An advantage of the closed-loop control system is the fact that the use of feedback makes the system response relatively insensitive to external disturbances and internal variations in system parameters. Thus, it is possible to use relatively inaccurate and inexpensive components to obtain precise control of a given system, whereas this is not possible in open loop systems.
> From a stability point of view, the open-loop control system is easier to build, because stability is a less significant issue. On the other hand, stability is an important problem in closed-loop systems, which can present a tendency to correct errors beyond what is necessary, causing oscillations of constant or variable amplitude. (OGATA, 2010, p. 7)

The choice of the most appropriate type of control system will depend on the designer's ability to anticipate the behavior of the related signals directly or indirectly. Once the basic elements of a system are understood, the next step is to define the control action that is most appropriate for the project. There are two very common control actions: *on-off control actions and* PID *control actions*[4].

[4] There are also control, proportional, integral and differential actions with individual or combined action. For more information on the subject, the author suggests consulting chapter 2.3 - Automatic control systems of the book Modern Control Engineering, OGATA (2010, p.14-24).

On-off Control Action

The on-off *control action consists of* the simplest control action in control and automation. Based on the information received, the controller should send the command to the actuator in order to change the system state to on or off. Also, according to OGATA (2010, p.19) "Two-position or *on-off* control is relatively simple and cheap and, for this reason, it is widely used in domestic and industrial control systems".

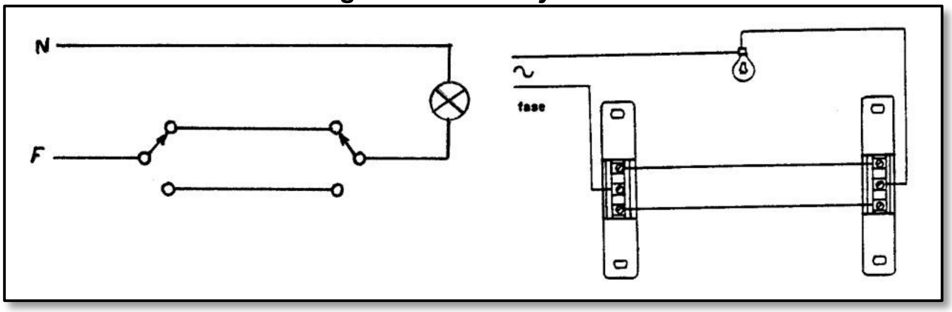
PID Control Action

The PID control action, proportional-integral-derivative, consists of a sophisticated control action. This control action combines the characteristics of proportional, integral, and derivative control systems. Compared to an *on-off control system*, the implementation of a PID control system requires a much wider range of information on the behavior of the system components. In addition to the mathematical rigor associated with the mathematical modeling employed.

TREEWAY CIRCUIT (PARALLEL CIRCUIT)

The *treeway* circuit or parallel circuit, represented by Figure 2, consists of a technique of installing switches so that the change of the state of the circuit can be performed from any of the switches. This type of connection is widely used for lamps that illuminate stairs and environments that need different points for turning on and off one or several lamps.

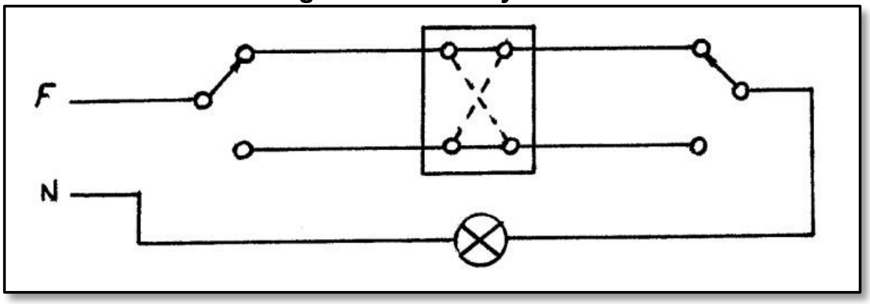
Figure 2 – *Treeway Circuit*



Source: Electrical handout, electrical drawing SENAI – ES, 1996, p. 29.

An extended version of the *treeway* circuit is the *fourway* circuit, represented by Figure 3, which makes use of three switches: two common parallel switches and a third specific switch placed in the middle of the link. In this way, the three switches control the status of the circuit lamp.

Figure 3 – *Fourway circuit*



Source: Electrical Handout, Electrical Design SENAI – ES, 1996, p. 30.

ARDUINO PROTOTYPING PLATFORM

The Arduino prototyping platform, represented by Figure 4, consists of a tool that allows the control of an electronic circuit through a microcontroller board. The information for the construction of circuits and electronic prototyping is easily found on the *web*, but with a purely didactic character. This platform has a whole structure for creating circuits and programming commands in a very flexible way.

It is important to reinforce the idea that, although the Arduino is called a microcontroller board, this device has the differential of being a platform with a favorable environment for the development of both *hardware* and *software*, in addition to diversified libraries, *shields*, and a network of collaborators who share codes, circuits, etc. Other microcontroller boards do not offer all these options. In this way, Arduino becomes an excellent tool for creating and testing new ideas and technologies.

Figure 4 – Representative model of the Arduino microcontroller

Source: Project Website - Instructables[5]

From a commercial point of view, the organization responsible for the rights and production of the Arduino platform requires that the project has the inscription "ino" in the name of the project. However, this is not necessary if the project uses a *standalone*

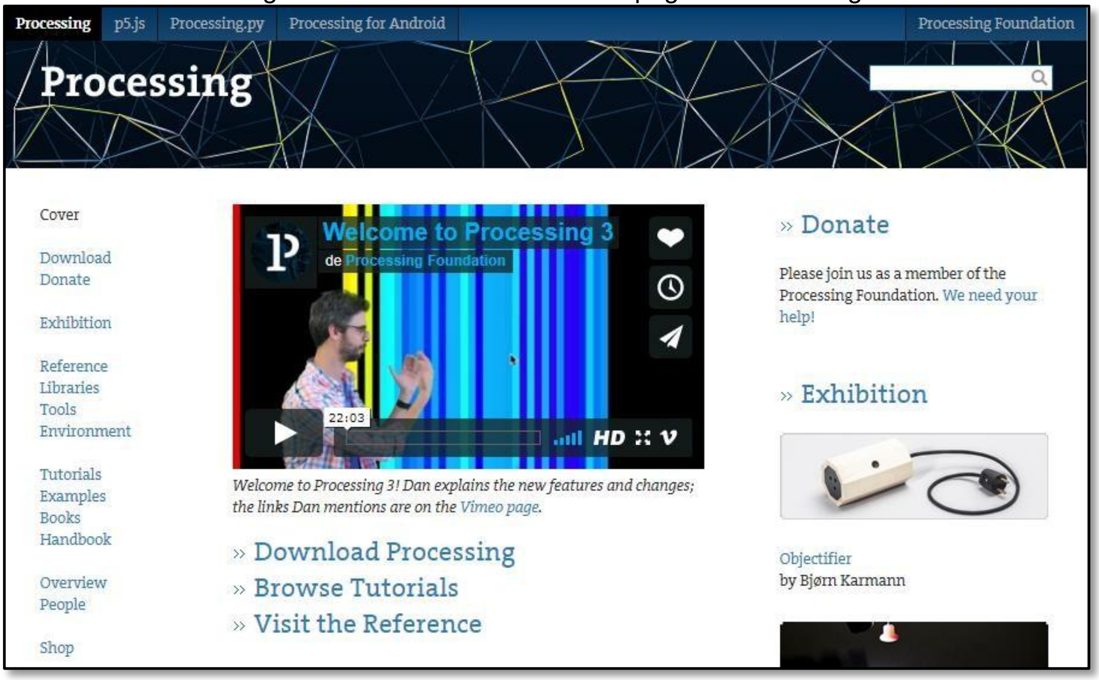
[5] Available at: < http://www.instructables.com/id/Beginner-Arduino/> Accessed in Aug. 2017.

version, that is, one that makes use only of the microcontroller itself (one of the components of the board) and not of all the features provided by the platform.

PROCESSING SCHEDULING PLATFORM

Processing is a Java-based graphical programming environment aimed at developers, artists, students, and enthusiasts who want to program, test ideas, create animations, and make graphic exhibitions. Like Arduino, *Processing* can be termed as a platform. It has its own development environment and can communicate with the Arduino platform via *Serial* communication, in addition to processing audio, data, image and text files. *Processing* emerged in an academic environment in 2004 at the Massachusetts *Institute of Technology (MIT*) in the USA and became popular in the following years. Figure 5 presents the *web page* where it is possible to download the programming environment and search for references about libraries, ideas and projects.

Figure 5 – Screenshot of the first page of Processing



Source: https://processing.org/

Processing is a platform that supports multiple *hardware architectures* and operating systems. The programming environment can run on MAC, Linux, Windows, and *Raspbian* devices (Linux operating system for Raspberry pi).

RASPBERRY PI

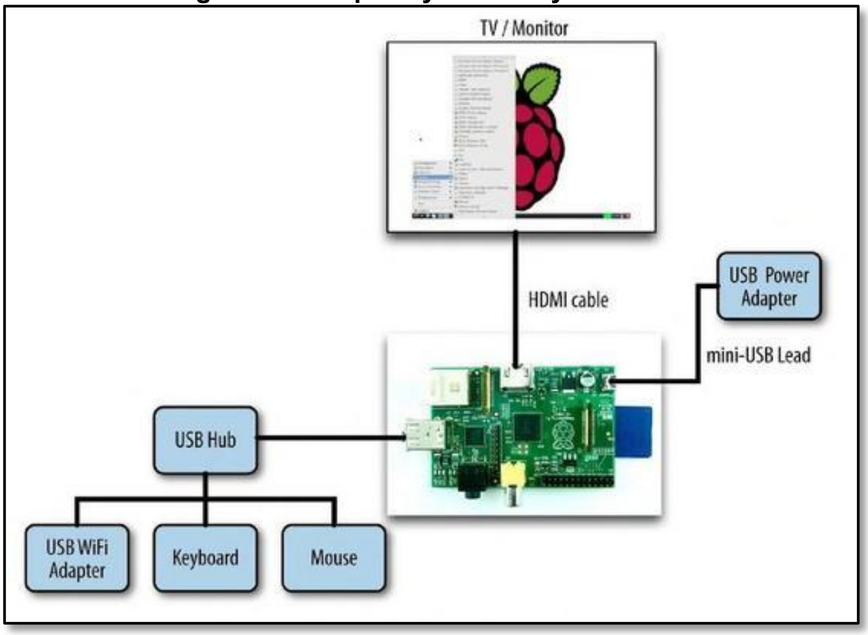
The *Raspberry* is a mini computer about the size of a credit card. Raspberry initially emerged as a project and developed to the point of becoming a Foundation. The goal of the

Raspberry Foundation is to offer digital insertion to people of various ages through programming. Raspberry became popular in England and in various parts of the world. The Foundation supports young developers, designers, teachers, hobbyists and companies:

> The *Raspberry Pi* Foundation works to make digital making reach the hands of all people around the world, so that they are able to understand and shape our growing digital world, able to solve the problems that matter to them, and able to work in the future.
> We provide low-cost, high-performance computers that people use to learn, solve problems, and have fun. We provide outreach and education activities to help more people access computing and digital creation. We develop free resources to help people learn about computing and how to do things with computers, and train educators who can guide others to learn[6]. (*Raspberry Pi Foundation*, 2017)

Raspberry can be used as a mini computer or as a mini *web* server. Being used as a computer, this device can be assembled to work according to the scheme shown in Figure 6.

Figure 6 – Raspberry assembly schematic



Source: *Raspberry Pi Cookbook*[7], Simon Monk, 2016.

[6] The Raspberry Pi Foundation works to put the power of digital making into the hands of people all over the world, so they are capable of understanding and shaping our increasingly digital world, able to solve the problems that matter to them, and equipped for the jobs of the future.
We provide low-cost, high-performance computers that people use to learn, solve problems and have fun. We provide outreach and education to help more people access computing and digital making. We develop free resources to help people learn about computing and how to make things with computers, and train educators who can guide other people to learn.
Available at: < https://www.raspberrypi.org/about/ > accessed in June 2017.

[7] Available at: < https://books.google.com.br/books?id=KkJRAgAAQBAJ&printsec=frontcover&hl=pt-BR&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false > Accessed in Aug. 2017.

In addition to compatibility with various peripherals, portability and ease of installation, another interesting feature of Raspberry is low power consumption. Figure 7 presents a Raspberry *Pi* 3 Model B Specification Table.

Figure 7 – *Raspberry Pi* 3 Model B Specifications

Table 1-2. Specifications of the Raspberry Pi 3 Model B

Release Date	February 2016
Architecture	ARMv8
SoC broadcom	BCM2837
CPU	1.2GHz 64-bit quad-core ARM Cortex-A53
GPU	Broadcom VideoCore IV (3D part of GPU @ 300MHz, video part of GPU @ 400MHz)
Memory	1 GB (shared with GPU)
USB	2.0 ports 4
Video output	HDMI rev 1.3 and Composite Video RCA jack
On-board storage	Micro SDHC slot
On-board network	10/100 Mbps Ethernet, Bluetooth, and WiFi
Power source	5V via MicroUSB
Power ratings	800 mA (4W)

Source: Raspbery cookbook, Simon Monk, 2016.]

CLOUD *COMPUTING TOOLS*

Cloud computing *tools consist of* web *systems* that allow the storage of files on the network itself (*cloud*). These files are available to all users who have permissions to access or even edit them. Dropbox, Google Drive, One Drive are examples of *Cloud Computing* tools. These tools have been widely used around the world and one hypothesis for the growing use of these tools is the need that many people and companies have to share information that is common to a certain group in which they are part. Of course, all these systems have their security and privacy policies in addition to providing a limit for storing files in the "cloud".

Figure 8 – Most Popular Cloud File Storage Tools

Source: Adaptation made by the author of the images found on Google Images.

Each "cloud" file storage tool has its specificity. Google Drive and One Drive both offer the option of editing files *online*. All the tools presented offer the option of editing from the computer itself, however Dropbox is more versatile in terms of file synchronization time[8].

MATERIALS AND METHODS

For the development of this work, several components related to the instrumental part were necessary, that is, all the circuits and components related to the sensor, the actuator and the conventional *treeway* circuit. For the assembly and configuration part, the devices to compose the controller unit, the platforms for configuring *hardware* and *software*, the tools and means necessary to put the entire system into operation were necessary.

MATERIALS

The materials for the construction of the proposed system can be classified into two categories: the materials related to instrumentation and the tools related to the simulation of the process and programming.

Instrumentation

For the construction of a system unit (control of only one lamp), the required components are listed in Table 1. For the controller only one unit is enough, as it must be able to control several lamps at once.

The careful choice of components and the consultation of prices are important for the construction of the instrumental part of the system, that is, it consists of the mechanical, electrical and electronic part of the project. In other words, it consists of the creation and construction of the hardware.

Table 1 - List of Components Required to Build a Basic System Unit

Components required for the construction of the Sensor
1N4007 Diodes Resistors Optical coupler **Components Required for Actuator Construction**
Male and female DC jack connector 1N4007 Diodes 5V Relay KRE 3T terminal connector Transistor BC 548 Resistors **Components required for the construction of the Controller**
Arduino UNO R3 Microintrolator

[8] Findings made by the author.

12V P4 plug power supply
Raspberry pi model 3B
Components required for the construction of the System (plant)
Parallel switch
Lamp socket
Lamp
Parallel wire

Source: Author himself.

Tools for process simulation and programming

Before putting the system into operation, it is essential to perform a simulation of the process or operation. This initiative helps to reduce risks inherent to the project and contributes to saving time and money. The sensor, actuator and plant circuits were simulated in a program commercialized by the multinational company *National Instruments*: *MultiSim 14.1 Student version*. This computer program allows you to visualize how the system will work, as well as assist in the proper choice of components. For the programming of the process, the tools used were the development environments of Arduino, *Processing* and the *Raspberry pi console.*

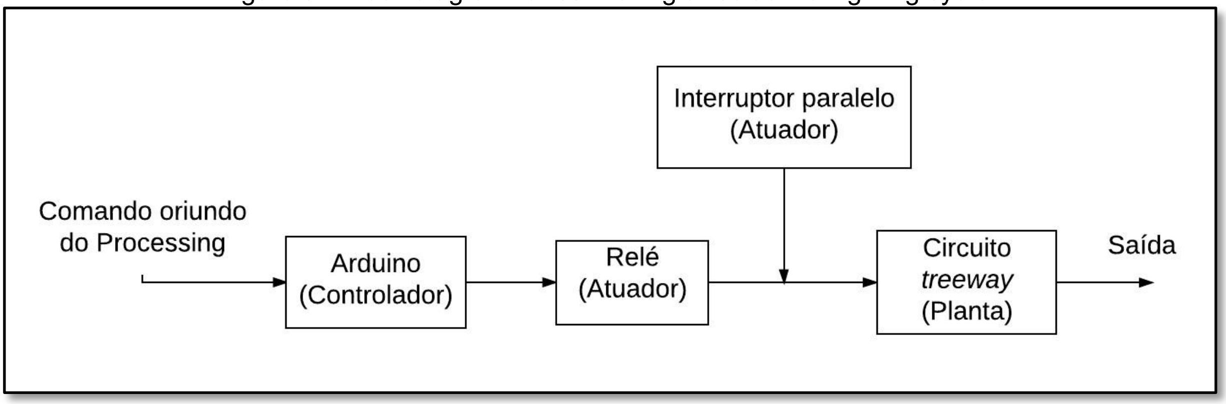
METHODS

In this section, the methodology and strategies adopted for the development of the system will be explained.

Structuring the control system

For the control of the lighting system, the first step was the study of the behavior of the system. Figure 9 shows the structured block diagram for the control of a light bulb in a residence.

Figure 9 - Block diagram for controlling a residential lighting system



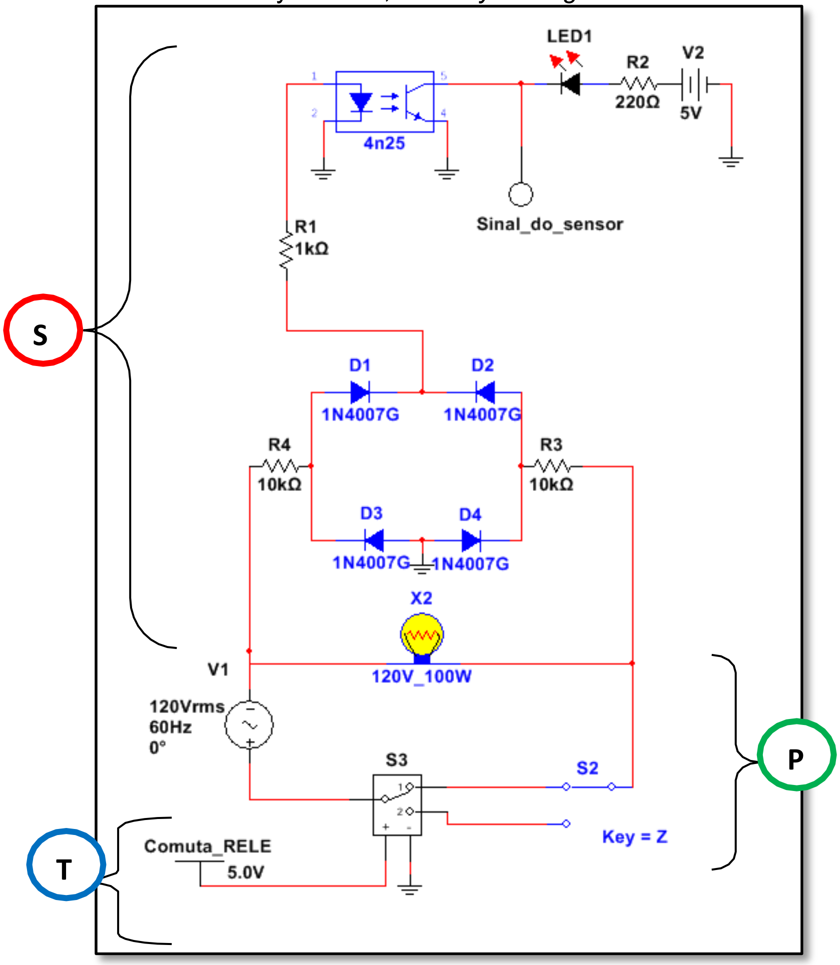
Source: Author's own production.

For the system shown in Figure 9, the Arduino microcontroller acts both as a controller, as it sends the electrical signals to the relay, and as a receiver of electrical signals from the sensor. In this system, Processing acts as a processing unit for information received and passed on to Arduino. The parallel switch consists of the other way of change in the state of the system. In this way, the system can be controlled electronically via the relay and mechanically via parallel switch switching.

Simulation in MultiSim Software

The Multisim 14.1 software, student version, allowed the construction of the basic circuit for the operation of the system. In the circuit represented in Figure 10, the circle represented by "A" corresponds to the actuator circuit, "P" corresponds to the floor and "S" corresponds to the part of the circuit related to the sensor. The main elements of the sensor are the rectifier bridge and the optical coupler; The main element of the plant is the *treeway configuration* made with the parallel switch and the relay; and the main element of the actuator is the relay.

Figure 10 – Circuit with relay module, *treeway configuration* and rectifier bridge



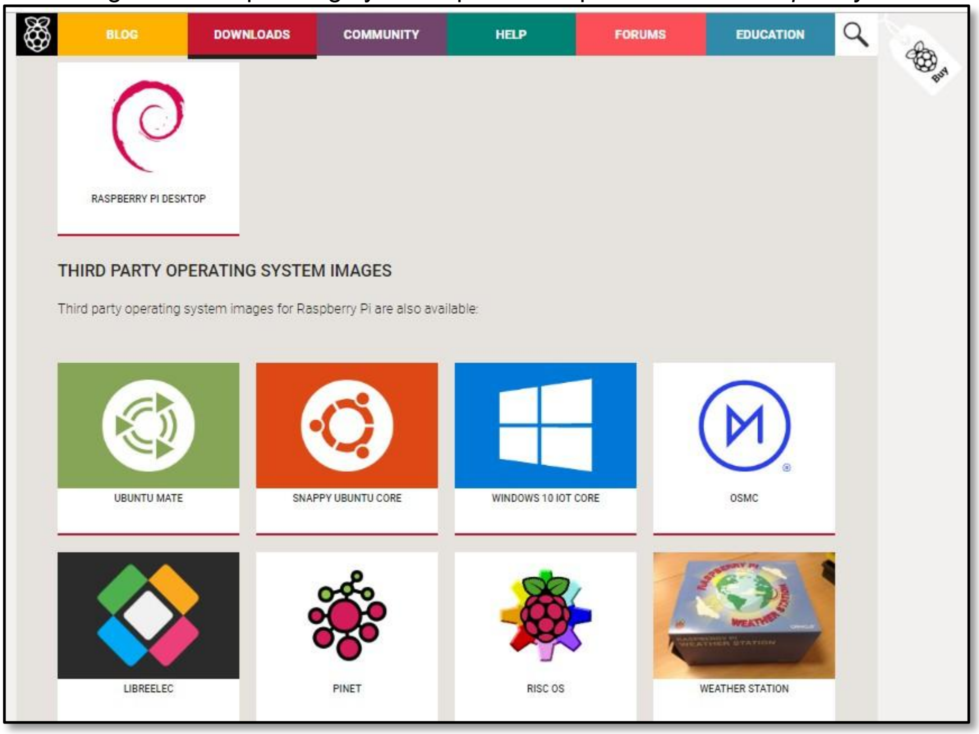
Source: Circuit made in Multisim software (adapted image).

In Figure 10 where it is indicated "sensor signal" refers to the signal that is sent to the Arduino when the lamp is on, that is, when the relay and the mechanical switch offer the conditions for the activation of the lamp. The 5V power supply indicated at the top of Figure 10 refers to the port on the Arduino that can be used as a power supply. In this way, the signal received by the Arduino originates from itself.

Raspberry Pi Configuration

Setting up the *Raspberry Pi* is relatively simple. The procedure basically consists of writing the operating system to the mini SD card. The Raspberry website itself provides several options for *downloading* operating systems compatible with the device (Figure 11). Some of these operating systems are based on Linux. There is also a version of Windows 10 (but intended for applications linked to the Internet of Things).

Figure 11 – Operating system options to operate on the *Raspberry Pi*



Source: Available at: < https:// www.raspberrypi.org/downloads/> Accessed in Aug. 2017

The operating system chosen for the project in question was *Raspbian*. This system is based on the Debian Linux operating system. Through consulting forums and code sharing networks, such as Github, for example, the configuration of *Raspbian* becomes relatively simple. Once installed, the operating system the next step is to install the applications that will be important for the operation of the system. These applications are installed by inserting command lines into the terminal.

Creation of the graphical interface in *Processing*

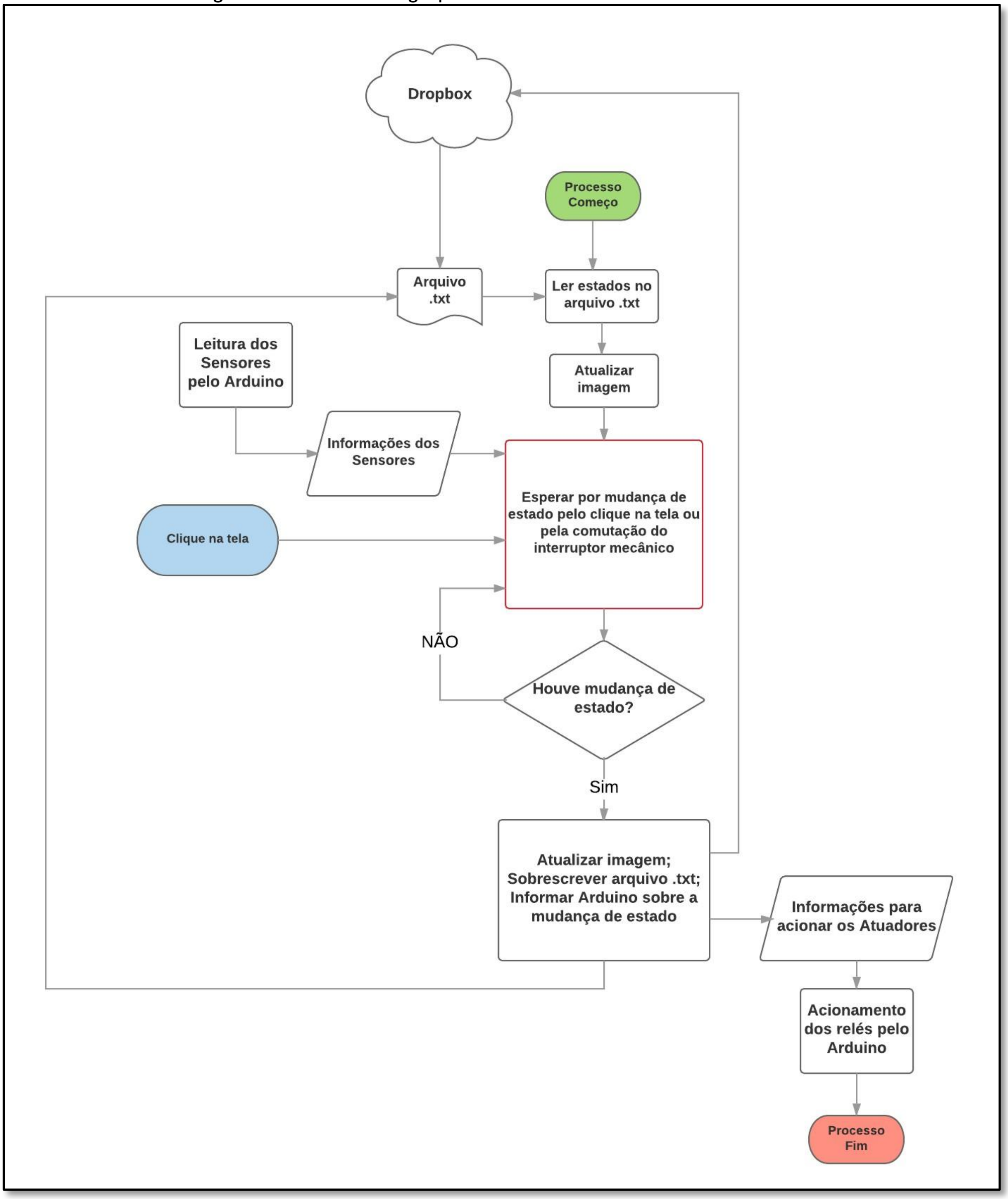
The main function of the graphical interface in *Processing* is to present an image that represents the illuminated rooms in the residence. A floor plan is ideal for this representation. In this way, Processing is configured to fetch information that indicates the desired status for the lamps (on or off). When clicking on the image, in the area delimited by the room, there will be a change of state (Figure 12). Processing draws a transparent yellow rectangle on top of the clicked area to indicate that the bulb is on. The rectangle is removed when a new click occurs indicating that the lamp is off.

Figure 12 - Creation of the graphical interface that will be presented to the user

Source: Author himself.

The general functioning of the logic applied to the code made in the Processing development environment and the relationship with the other components of the control system are detailed in the flowchart presented in Figure 13. In general, Processing has the function of accessing and saving information in the file with the extension *.txt* receiving information from sensors connected to the Arduino and ordering it to activate the actuators when necessary.

Figure 13 – Processing operation flowchart for control decisions



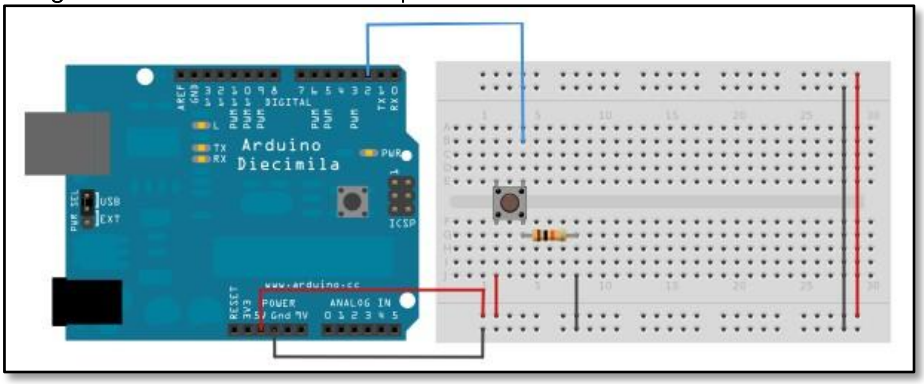
Source: Author himself.

Arduino Setup

Setting up Arduino is relatively simple. To assemble the system, it is necessary that the wires are well connected, since the signals from both the sensors and the actuators are uninterrupted. Another important point is the USB connection established between the Arduino and the *Raspberry*. The information sent and received by the Arduino is passed on via *Serial* communication through the USB port. Thus, for the system to work properly, the *Arduino's Serial communication must be fully available to communicate with the* Processing*.*

The sensor itself is the circuit of a relay module that acts as a normal open electronic switch. For the Arduino to correctly interpret the signal, it is necessary to place a *pull-down* resistor. Figure 14 shows the way the relay must be turned on so that the 5V signal properly reaches the Arduino when the lamp is on.

Figure 14 – Connection of an Open Normal Switch - *Pull-down connection*



Source: https:// www.arduino.cc/en/Tutorial/Button

For the interpretation of the *pull-down connection*, represented in Figure 14, the reasoning is as follows: the 5V signal leaves the Arduino port and goes straight to one of the terminals of the button (switch); in the other terminal, the blue wire is connected to the port where the signal will be sent at the time the switch is activated; in the same terminal, a resistor (above 10k□) is connected to ground. In this way, if the button is turned off, the signal that will reach the Arduino port will be 0V, and if the button is pressed, the signal will be 5V, since the resistor ensures the passage of most of the current to the Arduino port. The *pull-down denomination* indicates that in the normal condition (without activation) the signal that arrives at the port of the Arduino is a "low signal", that is, 0V.

The source of the 5V signal is the Arduino's own power port. If this power port is used by many devices, there is a risk to signal quality, as it overloads the Arduino.

The relay module that will serve for the electronic control of the lamps has power supplied from an external source. However, the signal that arrives at the base of the transistor (or optical coupler) comes from the Arduino's digital ports.

Setting up Dropbox on multiple platforms

The Dropbox configuration is specific to each platform you use. The *desktop* version is easily configurable on Windows, Linux, and MAC platforms. For *Raspberry* and tablets/*smartphones,* the use of auxiliary programs is required.

On *Raspberry*, Dropbox is set up by downloading the files via the command line. This is a special version for developers. On mobile, Dropbox only allows access to files directly in the "cloud" so that the files can be viewed but are not saved in the device's memory. In order for the desired file to be saved in the device's memory, it was necessary to install a specific application for this purpose: *Dropsync files*, which allows synchronization with the cloud after saving the file.

Dropbox's primary function is to make the file with the extensão.txt accessible to all platforms running the graphical interface created in *Processing*. Synchronization is an aspect that must be taken into account for the proper functioning of the system.

RESULTS AND DISCUSSIONS

In this part of the work, analyses will be carried out on the implementation of the control system as well as the implications during the testing phase. A simplified cost analysis was also added in order to verify the economic feasibility of implementing the system.

ANALYSIS OF THE OPERATION OF THE GRAPHICAL INTERFACE

The justification for this choice is due to the fact that it makes the idea presentable to an ordinary user. A user-friendly graphical interface is the means of contact between user and system. This part made it possible to raise some points that would be interesting for the user:

- When clicking on the screen, it is important that the activation is as fast as possible;
- The graphical interface must be intuitive and faithful to the structure of the residence;
- A notification that there has been a change of state would give the assurance that the action has in fact been carried out;
- A home screen that asks the user for a password would be very convenient to assure the user that only he and authorized people have access to control the lamps in the residence.

For this project, only the first two points were valued. Since no practical ways were found to solve the others. However, all these points must be taken into account in the event that this idea can be converted into a product or service.

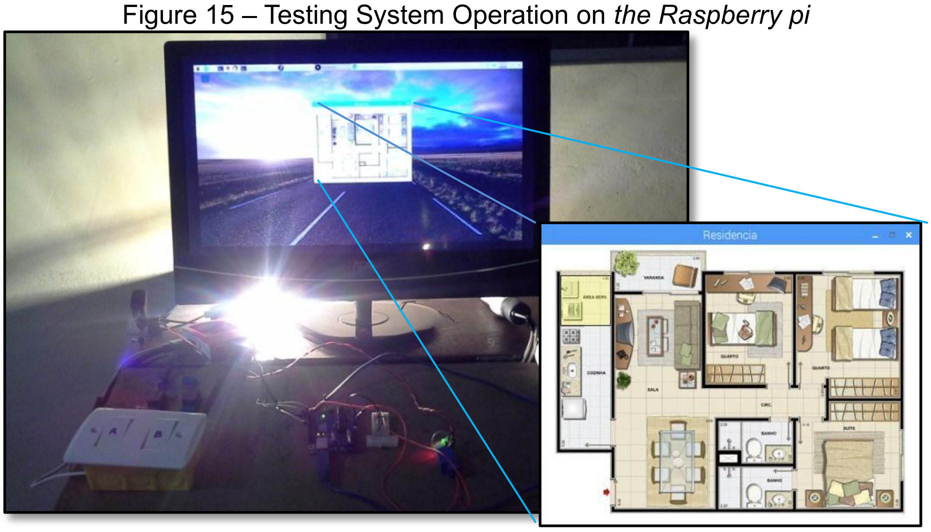
ANALYSIS ON THE CONSTRUCTION OF A BASIC UNIT OF THE SYSTEM

With regard to the construction itself, it was not possible to acquire all the electrical and electronic components of the controlled circuit shown in Figure 12. At first, the analysis was reduced to just a single base circuit. The purpose of this assembly was precisely to evaluate the behavior of the actuator and sensor. For a basic system unit (single-lamp circuit), the Arduino must accurately read the signal from the sensor and send a consistent signal to the actuator.

By using many wires during assembly, it was found that the sensor's electrical signal reading was not accurate. The signal was discontinuous, an undesirable characteristic for the system, because it could happen that the lamp was on, but information would be sent to *the Processing* that the system would be deactivated, in order to present untrue information to the user who was in contact with the graphical interface locally or remotely, which would be worse. For the actuator, the Arduino worked perfectly, with no imbalance in the signal. However, there was no construction of the circuit responsible for ensuring the position (actuation state) of the relay. Thus, if there is a failure in the activation of the Arduino power supply system, it is likely that there will be a shutdown or even an undesirable activation of the lamp during the time interval corresponding to the interruption.

Figure 15 shows the system operation test from the association of all components. The working lamp (left side of Figure 15) was activated electronically.

Figure 15 – Testing System Operation on *the Raspberry pi*



Source: Author's own production

Figure 16 shows the circuit components in operation. The switch with the inscription "A" at the bottom left of Figure 16 indicates the possibility of turning off the lamp mechanically. For this assembly, it was decided to use a mobile phone charger to replace the part of the sensor circuit responsible for converting alternating current into direct current (rectifier bridge). Due to the instabilities in the output signals of the optical coupler, a relay module was used instead. It was observed that the activation of the sensor relay (installed as a normal electronic switch open on the Arduino) by the cell phone charger was not immediate, but the signal that reached the Arduino was uniform.

Figure 16 – Testing of system components (left) and result of the activation of the first lamp (right)

Source: Author's own production

The left side of Figure 16 corresponds to the result of the lamp activation in the graphical interface made in *Processing*. As the number of sensors and actuators connected to the Arduino increases, the greater the complexity of the connections. This first test shows the importance of creating installation and maintenance manuals. From a commercial point of view, leaving too many strands exposed gives a negative image to the product. Thus, for the normal operating situation, the wires must be located inside conduits. The sensors, actuators and the microcontroller would be in boxes suitable for electrical components in respect of safety conditions. What would be presented, in fact, to the user would only be the lamps and the panel.

ANALYSIS OF THE PROGRAMMING LANGUAGES USED IN THE SYSTEM

The controller of this system was not modeled following the classical methodologies of modeling modern control systems. Thus, the approach that involved the frequency domain was not necessary. All methods were applied directly in the time domain.

The controller's activities were determined in a pragmatic way, that is, the Arduino was programmed exclusively to collect the information and make it available to the *Processing*. Arduino only triggers the actuator when the user requests the state change through *Processing*. In this way, the Arduino was programmed to be a task executor device while *the Processing* was programmed to be the management of tasks and information.

Regarding the passage of information between Processing and Arduino, communication between Arduino and *Processing* via USB *Serial* is very limited. When information is transmitted in the *Processing* sense to Arduino, it is only possible to send one text character at a time. When this occurs in the Arduino sense for *Processing*, it is only possible to send one number at a time (this number is any integer between 0 and 255). Such particularities require good programming practices and a lot of astuteness on the part of the programmers of the codes that will be compiled on these platforms [6].

There are other programming languages that could be used in this project, such as the *Python* language. The *Python language* is widely considered in projects with *Raspberry pi*. In fact, the *Raspbian* operating system itself already comes with the development environment ready for it. Regardless of the programming language adopted to process information from Arduino, it is essential that the result is aligned with the user's expectations.

ANALYSIS ON SYNCHRONIZATION TIME

When saving the data file in the folder synchronized with Dropbox, the synchronization time of the text file was checked based on the platform used. Taking *Raspberry* as the main computer, the time needed for information with the "cloud" was:

Table 2 - System Data File Sync Times in Dropbox

Command source graphical interface	Synchronization time (in seconds)
Raspberry (connected to Arduino)	Requires User Action [6]
Notebook	2
Cell phone	38
Tablet	19

Source: Devices owned by the author. [6] The version of Dropbox available for the Raspberry Pi family does not automatically sync changes to files. The user must do the synchronization on their own through command lines in the terminal.

Despite the difficulty of synchronizing with Dropbox, Raspberry is very effective in local command, that is, in triggering without the need for an internet connection. When accessed and controlled remotely, the response time will depend on the processing capacity of the platform on which the graphical interface runs and also on the quality of the internet connection.

BRIEF STUDY ON COSTS

Evaluating the amount of financial resources employed in a project is of fundamental importance for both the manufacturer and the consumer. The project in question is still in the prototype phase, so it is likely that there will be a lot of discrepancy in relation to the quantities and prices adopted. The study on costs was restricted to the relative cost of the fundamental components. The lamp itself was not added, as it was assumed that the lighting system of the residence already existed. The new design would retain the characteristics of the previous system and offer the advantages of electronic control. Table 3 gathers the list of quantities and prices of the materials that offered the best performance in the testing phase.

Table 3 - Price list of items that performed well in the first phase of testing

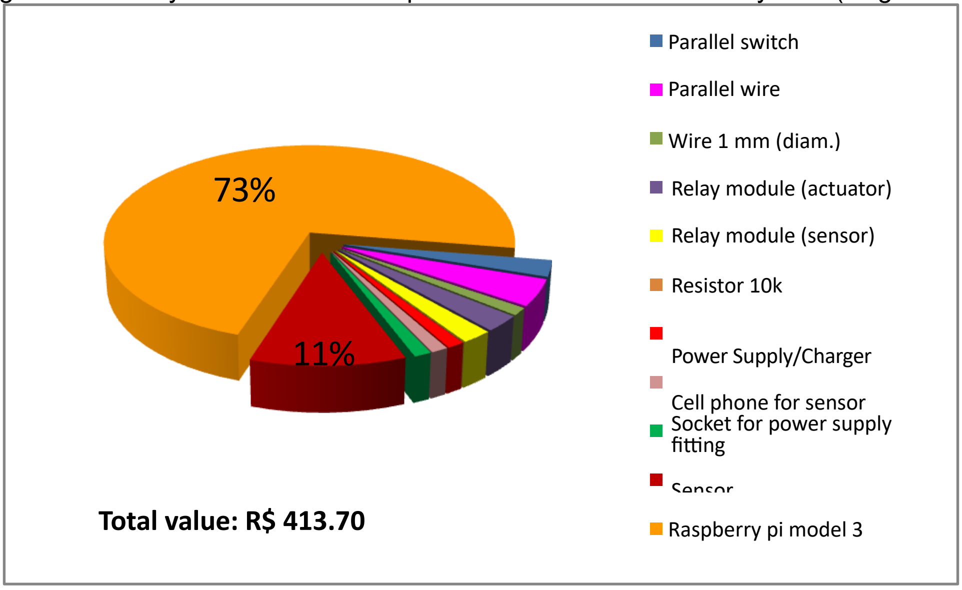
Item	Unit value	Basic Quantity	Total (un. Basic)	Quantity ref. to the entire residence	Total (11 pcs.)
Parallel switch	R$ 10,90	1	R$ 10,90	11	R$ 119,90
Parallel wire	R$ 1,50	12	R$ 18,00	132	R$ 198,00
Wire 1 mm (diam.)	R$ 0.65	8	R$ 5,20	88	R$ 57,20
Relay module (actuator)	R$ 10,90	1	R$ 10,90	11	R$ 119,90
Relay module (sensor)	R$ 8,90	1	R$ 8,90	11	R$ 97,90
10k Resistor	R$ 0.10	1	R$ 0.10	11	R$ 1,10
Cell Phone Charger/Charger for Sensor	R$ 5,00	1	R$ 5,00	11	R$ 55,00
Socket for fitting the sensor source	R$ 4,90	1	R$ 4,90	11	R$ 53,90
Relay power supply (actuator)	R$ 5,00	1	R$ 5,00	11	R$ 55,00
Arduino Microcontroller	R$ 44,90	1	R$ 44,90	1	R$ 74,907
***Raspberry pi* model 3**	R$ 299,90	1	R$ 299,90	1	R$ 299,90
			R$ 413,70		**1.132,70**

Source: Electrical and electronic material stores. [7] Value corresponding to an Arduino Mega board that has a larger number of digital ports.

Table 3 differs from Table 1 in terms of the mode of implementation of the system. The items in Table 1 are for the construction condition of all sensor and actuator boards, this option would require more time for production. Table 3 assumes that the system will be developed from ready-made modules, that is, modules that require only assembly and adjustment, which would require less time for production.

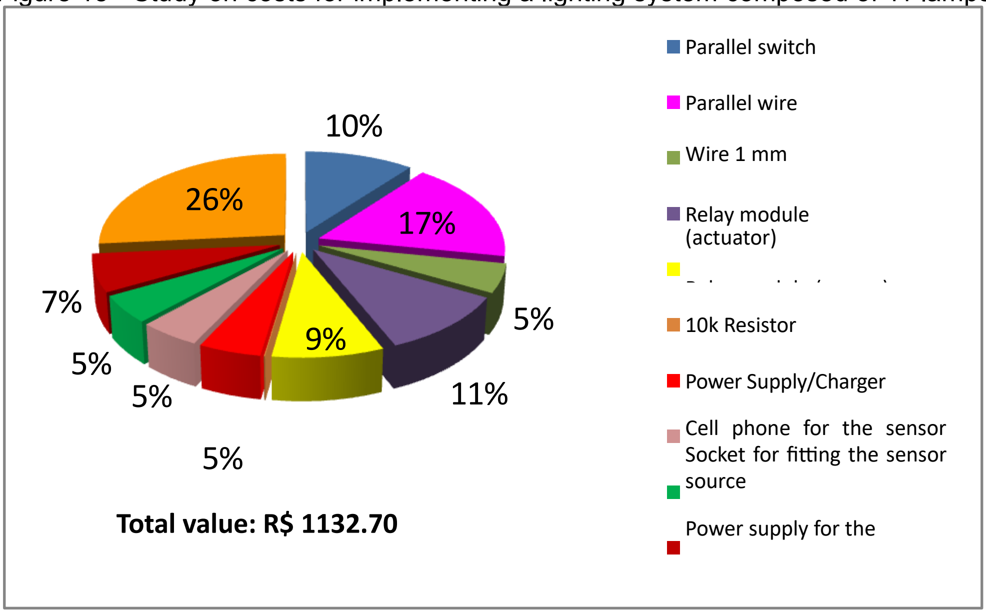
Based on Table 3, Figures 17 and 18 present the results of the study on the costs of the fundamental components for the implementation of the system.

Figure 17 - Study on costs for the implementation of a unit of the system (single lamp)



Source: Values presented in Table 3.

Figure 18 - Study on costs for implementing a lighting system composed of 11 lamps



Source: Values presented in Table 3.

The values referring to the controller unit composed of *Raspberry* and Arduino in Figures 17 and 18 have little variation. Although the controller set (Raspberry-Arduino) corresponds to 84% of the project's implementation investment, this percentage tends to fall as the number of lamps to be controlled is increased. As shown in Figure 18, the cost portion corresponding to the controlling set is equivalent to 33%.

In percentage terms, the values of the sensors, actuators and power supplies are equivalent. One strategy for reducing costs is to negotiate the prices of components at the wholesale and retail levels.

The construction of the modules can be an alternative for reducing costs. However, it requires greater knowledge in electronics, formal procedures and safety standards.

For the purpose of replacing or complementing the existing lamp drive system (mechanical drive), the control system presented is a very expensive alternative. However, the improvement of sensors and actuators, as well as the protection techniques and configuration of this equipment are ways to make the project more attractive to the consumer.

ANALYSIS OF CRITICAL POINTS AND SUGGESTIONS FOR IMPROVEMENT

The prototype presented in this work is still in the testing phase. And by putting it into operation, it was possible to direct what would be the critical points for the lamp control system in a home based on the proposed techniques and technologies. The critical points were classified into two categories: critical points related to *hardware* and critical points related to *software*:

Critical points related to *hardware*

The critical points that are related to the *hardware* are mainly related to the Arduino, the board of the sensors and actuators. They are:

- Excess of wires coming in and out of the Arduino;
- Risk of bad contact and short circuit of the wires that connect the sensors and actuators to the Arduino;
- Difficulty in allocating sensors and actuators in the case of a real system;
- It requires greater rigor in the manufacture of electrical contacts and terminals.

In general, the problems are associated with the connecting wires and the quality of the devices themselves, both sensors and actuators. The level of demand in the quality of sensors is higher than that of actuators. The screen refresh time depends on the response time of the sensors. And cause and effect analyses on the behavior of both sensors and actuators were not performed in this work.

Critical points related to *software*

The smooth functioning of *software* is closely linked to the smooth functioning of hardware. To act correctly, *Processing*, performed on *Raspberry*, depends on the information provided by Arduino. It is based on the information that decision-making (control actions) will be carried out properly. The *software* is still very open to the common user, who even has access to the source code used in *Processing*. The execution of the graphical interface occurs through the compilation of the *script* so that any change in the code can influence the final result. Briefly, the critical points related to software are:

- Vulnerability of the data storage file, since it is available on the device that is connected to the system;
- There are a significant amount of steps for the user to turn on the system;
- Execution through command lines in *Raspberry* is unconventional to the average user;
- Difficulty syncing with Dropbox via remote devices.

In general, the critical points related to *software* are closely linked to the techniques used to build the graphical interface, the storage and protection of information.

POSITIVE POINTS ABOUT THE OPERATION OF THE SYSTEM

Despite the difficulties related to hardware and software, presented in Section 5.6. The designed system offers greater convenience to the user, who is informed about the operation of the lamps in his residence and can control them in the traditional way or through the screen of a computer, *tablet* or *smartphone* in order to contribute to the rational consumption of electricity,

The cost of implementing the system is relatively high. However, the materials used in the prototype are easy to install. Practicality, in installation, is an important parameter for the system to become marketable.

CONCLUSION

In this work, programming, electronic prototyping, and cloud computing tools were presented , which, properly associated, enable the creation of a lighting system to control the lighting system of a home. The knowledge of instrumentation, electrical/electronic circuits and control and automation techniques played an important role in the development of the project.

The simulation carried out in the Multisim 14.1 software allowed important decisions to be made for the development of the project. However, there were difficulties when making the sensor and actuator plates. Difficulties necessitated the procurement of manufactured relay modules. This change caused a gain in manufacturing time, however with relatively high costs.

The installed and tested unit was fast at the local level, mechanically and electronically. The operation was slow when the system was connected to the internet due to the delay in syncing the information with Dropbox. Dropbox, in turn, needs special operating conditions for each platform used.

The system lacks improvements in both *hardware* and *software*. With regard to *hardware* improvements, it is necessary to develop techniques that enable ease of installation and reduction of risks related to short circuits, in addition to reducing the number of wires. For the improvement of the *software* used in Arduino and *Processing* , it is necessary to study techniques of programming, protection and association of systems.

Finally, the study of the costs of the main components of the system allowed to evaluate the need for optimization of the components so that the idea is more attractive to the potential consumer, of the products and services, of the projected control system.

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