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ANDROID APPLICATION FOR IDENTIFICATION OF VEHICLE PLATES FOR TRAFFIC INSPECTION

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ABSTRACT

Traffic inspection is present in the daily lives of drivers. However, this inspectional process often presents itself in an inefficient and archaic way, by using paper and pen to write down the infractions committed, especially in regions lacking the latest technology. Thus, the objective of this work is to present a possible solution to this problem, with the development of a prototype application that allows the user to perform these inspections in a digital way. The methodology used includes a visit to *City Cooperation Center (Centro de Cooperação da Cidade - CCC)* in Manaus, Amazonas, to analyze the current scenario of the city's traffic inspection system, as well as the determination of methods to integrate the information between the application developed and PRODAM's database. At the end of the research and development, the significant potential to aid traffic agents is verified, and presents direction for future research in the area to improve what was developed in this work.



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I. INTRODUCTION

Over time, new technologies are designed, developed, and tested. One of these innovations was the automobile, bringing people and places together, facilitating tasks and revolutionizing modern society. But like every invention, the automobile brought new problems and intensified existing ones, which are fought through inspections that have been intensified in recent years with the upbringing of electronic inspection that although it lacks formal coordination, the actions taken by municipal bodies when added together are of the same size as a national inspection program [1]. Today, the big urban centers in Brazil and in the world, as in our neighbors Chile and Argentina, which had their traffic codes changed respectively in 1995 and 1999 [1], count on extremely modern and powerful systems to help in the daily tasks of traffic inspectors and traffic agents, methods such as OCR (Optical Character Recognition), software for license plate recognition and even faces, as in the port city of Itapoá in Santa Catarina, that uses

OCR technology to check the biometric registration of the driver and vehicle to verify if there is any cargo delivery scheduled for that day and/or time [2].

SENATRAN is the union body constituted with the purpose of representing public transport companies in the city of Manaus, responsible for enforcing traffic legislation, established by National Traffic Council (*Conselho Nacional de Trânsito - CONTRAN*). It, through its traffic agents, inspects vehicular infractions, such as stopping and/or prohibited parking, speed above the permitted limit, among others.

To carry out the inspection, traffic agents often resort to snapshots of the offending vehicle's license plate, to later register manually in the secretariat's system, so that the offender is properly treated and punished. However, this form of inspection can prove to be inefficient, as it requires a lot of repetitive and completely manual work, reducing the productivity of the service, using a slow and outdated system. How to adapt this existing system to the most practical, fast platform and using all that technology has to offer?

In the development of this work, two notebooks with different specifications are used and discussed in the materials and methods section. Several tools, described below, are also used: Figma, for designing the application screen layouts; *Android Studio*, for application development.

Code libraries, described here, are also used during the development process: Google ML KIT Text Recognition API (Google's Machine Learning Kit text recognition API), for recognizing the text on license plates; Hilt, for injecting dependencies into the application project; Data Binding, for the separation of user interface (UI) logic from business logic – that is, the code that defines the application's logical operations, not related to the graphical interface, but how it will behave upon user actions; Room Database, local database implementation abstraction library on Android; and CameraX, to handle the user's device camera.

At the end of development, the system is first tested by the developers and authors of this work, and then it is tested by the transit agents selected later to obtain feedback from them so that possible errors in the flow or operation of the application can be corrected, and, finally, an analysis of the impact of this project on the routine of transit agents is carried out.

II. THEORETICAL REFERENCE

II.1 PATTERN RECOGNITION

II.1.1 General Concepts

The most notable quality of Pattern Recognition (PR) is undoubtedly its remarkable scope when used in various fields of research [4]. Being able to act in several fields as already mentioned, with these going from the analysis of images to temperature, sound etc. Two of these areas of action will be discussed in the continuation of this work.

This area is not new, but before computers and the consequent increase in demand for them, PR did not extend to more than the field of theoretical statistics.

A complete recognition system is composed of a sensor capable of capturing the information to be analyzed (an image, sound, temperature, etc.), a machine capable of extracting, reading, and computing the information obtained by the sensor, whether this information is in numerical or symbolic and finally a model is needed to classify the acquired and analyzed data and this model in question is dependent on the data obtained.

II.1.2 Application

In terms of applications, this area is very broad as previously described, that is, even though it is unique and objectively for the analysis of captured data, these can be from different origins and for different purposes. PR is present (and in a way makes up the whole) in the analysis of satellite images, in biometric recognition (facial, voice, etc.), archival classification, among other diverse functions.

Still in terms of applicability, several PR techniques were created over time and with the growing need for data computing systems, techniques based on Artificial Intelligence (e.g., neural networks), statistical and mathematical analysis [3].

II.2 DIGITAL IMAGE PROCESSING

II.2.1 General Concepts

This field is composed of algorithms prepared for specific purposes, thus providing the user with a tool with a wide diversity of forms and processing modes. They interpret images in a

mathematical way as if they were data directly related to the method of its creation [3].

In other words, this area is responsible for analyzing information from multiple dimensions captured by different sensory methods.

II.2.2 Application

Since the space race in the 20th century, this area has been gaining more and more body and strength mainly due to its applications in the beginnings of orbital flights until the advent of satellites, but we cannot forget that it is present in the solution of a variety of questions, that even not always related, need methods capable of improving visual information to make its interpretation easier for humans [5].

It is also present in areas such as medicine, where, thanks to functions such as contrast control, it allows better quality in x-ray images, ultrasounds, radiographs, among other types of imaging exams. As previously mentioned, this field also works in the meteorological area thanks to the increasingly advanced satellites.

II.3 OPTICAL CHARACTER RECOGNITION

II.3.1 General Concepts

Known by its name in English (Optical Character Recognition) it is the method that allows, as the name itself already specifies, the recognition of characters, the optical part comes from the fact that this recognition is done from the interpretation of the information contained in a file of image, the characters in this file may have been typed on a computer, written manually on a sheet of paper, printed, etc.

OCR has as its main purpose the simulation of the human capacity of reading and textual comprehension, although it is not fully capable of such a feat [6].

II.3.2 Application

OCR made it possible to create several tools that help us immensely, from performing simple day-to-day tasks such as scanning documents, reading codes through cell phone cameras, thus allowing greater automation of services, cloud text storage it, OCR, also helps in jobs that require greater detail such as analysis, reading, digitization of transcription of ancient texts by researchers and historians.

II.4 MACHINE LEARNING

The purpose of Machine Learning - or Machine Learning - is to study, design and improve mathematical models that can be trained (once or continuously) with contextualized data (from a generic environment), to infer the future and make decisions without knowledge. completeness of all influencing elements (external factors) [7]. To put it another way, machine learning consists of building programs that can adapt to the environment in which they are implemented, without having full knowledge of everything that can change their previously defined parameters. According to [8], the area of machine learning is divided into four groups, which will be discussed below.

II.4.1 Supervised Learning

In a supervised setting, the algorithms are like a student being supervised by their teachers, were, in the context of machine learning, this would be the training data for the algorithm. In this way, as the algorithm makes mistakes, it corrects itself from the data inputs it receives, like a student being corrected by his teacher [7].

In supervised algorithms, data classes are predefined, being created in a finite set, defined by a human, to be classified (the process called labeling) by the algorithm [8] (Figure 1). Within this

group of machine learning algorithms, [8] comments on the existence of two main supervised models: classification and regression models.

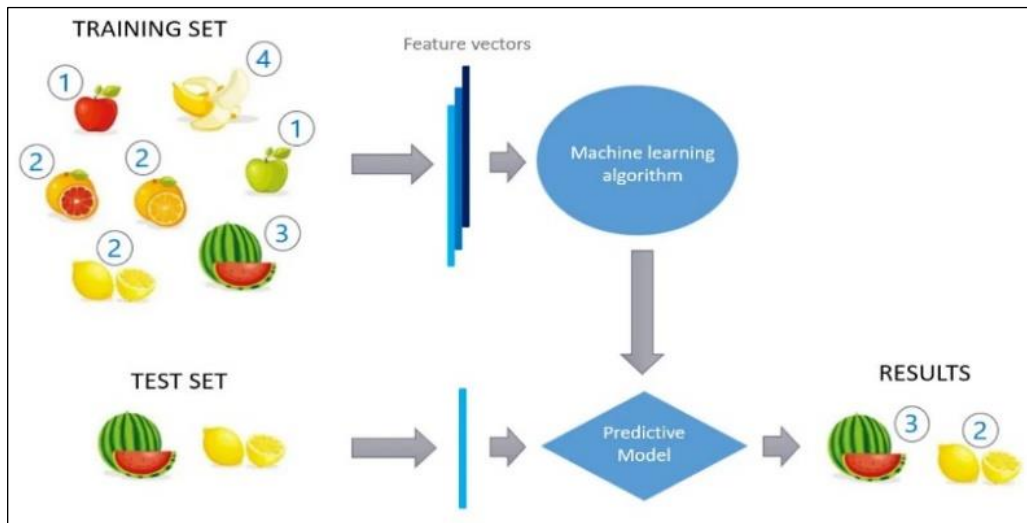


Figure 1: Supervised Learning Diagram.
Source: [9].

II.4.1.1 Classification Models

This model is a supervised learning method that consists of assigning a label to a sample based on its attributes [10].

II.4.1.2 Regression Models

Very similar to the classification model, the regression model has quantitative values as a response variable instead of qualitative ones [10]. That is, instead of predicting labels, this model aims to predict numerical continuous values [10].

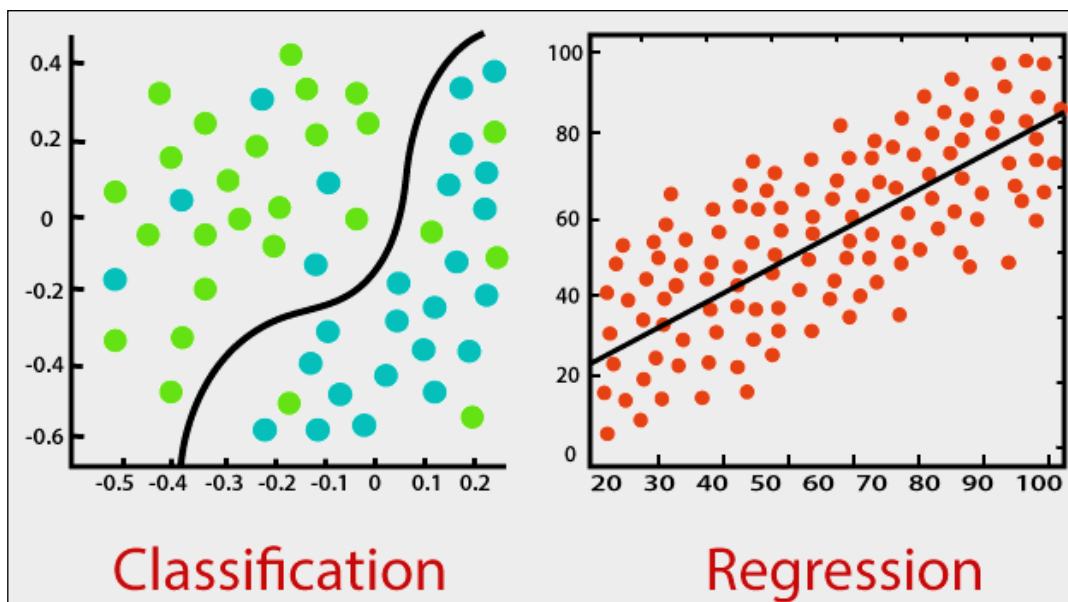


Figure 2: Classification X Regression.
Source: [11].

II.4.1.3 Use Case

A very interesting, supervised learning use case that can be noted is a study by [12] in which he used predictive analysis, which is nothing more than the application of supervised learning, to predict death cases in 5 years of life. Elderly participants in the Health Welfare and Aging (SABE) study. Another study by [12] was to predict the lifetime risk for cancer patients, with quality of up to 30 days.

II.4.2 Supervised Learning

Unsupervised learning is based on the absence of any previously defined supervisor, and thus also absent of error measures. It can be useful when the algorithm needs to learn to group (a process called clustering) a random group of elements according to their similarities [7].

Therefore, it may seem somewhat mysterious to imagine what the algorithm could learn without having much information about the inputs and expected outputs; however, its objective is not

to classify, but to group by similarities [13]. Within this type of machine learning, [13] also states that there are two ways to apply unsupervised learning: clustering and dimensionality reduction, which will be dealt with in the following topics.

II.4.2.1 Clustering

It is the process of grouping similar data into different groups, that is, the partitioning of a group of data into subgroups, whose data follow whatever distance measure is defined [14]. It can also be used for the detection of anomalies in the data group, as was done in a proposal of this implementation in data from multiple views [15].

II.4.2.2 Dimensionality Reduction

Dimensionality Reduction is the process of transforming large data into a meaningful, reduced-dimensional representation. Ideally, this reduced dimension should be the same as the intrinsic dimensionality of the data, which is nothing more than the smallest dimension of parameters needed to work with the original data [16].

II.4.2.3 Use Case

An example of the use of unsupervised learning that cannot be overlooked is the video recommendation algorithm on the Youtube website. He uses the tool created by his company, Google, called Google Brain, which uses the techniques and methodologies of this learning to recommend videos that the algorithm judges (or predicts) that the user is more likely to watch [17].

II.4.3 Semi-Supervised Learning

This type of learning brings together the supervised and unsupervised learning paradigms and develops a paradigm of its own, with the aim of studying how computers and natural systems (such as human beings) learn when presented with both labeled and unlabeled data [18]. He mixes the concepts and methods defined in both paradigms to understand how this can affect the algorithm's learning outcomes, developing algorithms that take advantage of these conditions [18].

Also, according to [18], this type of learning is of great interest in machine learning and data mining, because due to its nature it can improve the solutions of the problems that supervised or unsupervised learning solves, that is, it uses the best factors of both types for a better implementation (Figure 3).

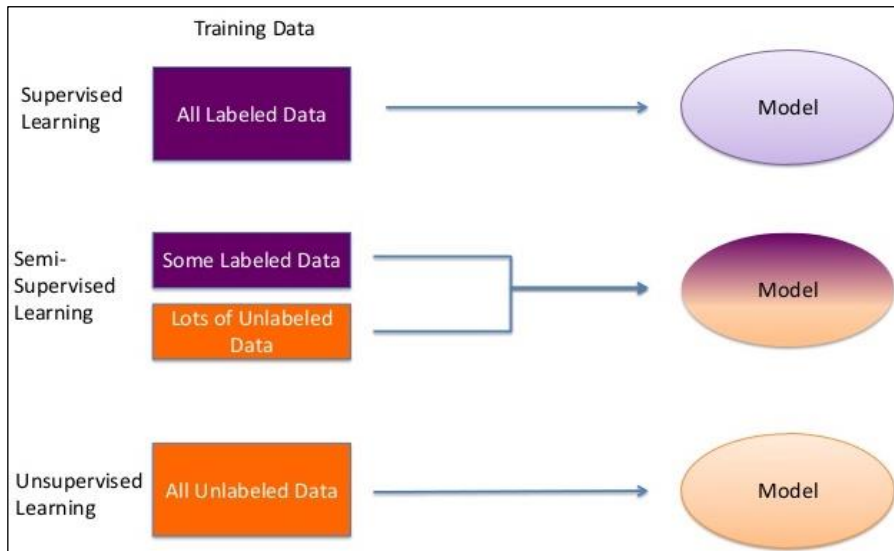


Figure 3: Diagram of the semi-supervised learning concept. Source: [19].

II.4.3.1 Use case

An interesting use case of this type of learning is performed by [20], in which it was used to identify people in webcams.

II.4.4 Reinforcement learning

Reinforcement learning refers to the behavior of algorithms that learn through trial-and-error interactions with a dynamic environment [21]. According to [21], there are two main strategies to solve problems involving reinforcement learning. The first one is searching the behavior space to find one that performs well in the environment.

In other words, the algorithm analyzes all the behaviors that it can take when it finds itself and seeks to choose the best among them to get closer to the objective defined for it. The second consists of using statistical techniques and dynamic programming methods to estimate the usefulness of taking actions in the states of the world - that is, using statistics to determine the best action to be taken, aiming at the environment in which it is currently found.

II.4.4.1 Learning stages

The [20] says that all reinforcement learning must go through a cycle of learning stages. This cycle consists of the algorithm being presented with a state of the environment, together with the available behavior options against that current state, and then the algorithm must choose, usually by a trial-and-error system, the option that will accumulate the most points of reinforcement in the long term, which means that he will get as close as possible to the objective proposed to him. To better understand this cycle, [20] presents the following scheme:

In Figure 4, the learning cycle to which [20] refers is shown. In it, the environment and the algorithm (Agent) interact with each other. First, the environment tells the algorithm which state it is in, and how many and which behavior options it can adopt. The algorithm then makes the choice, and then the environment returns to the algorithm the amount of reinforcement points it received for having performed the previously chosen action. These points are what indicate to the algorithm if it has made an excellent or a bad

choice, in relation to the objective to be reached. In [22] the author also discusses reinforcement learning, stating that this process basically consists of periodic state updates, with “rewards” – such as receiving more points, no points, or losing points – according to

the steps taken by the algorithm. In the following, a whole reinforcement learning process will be exemplified with a maze problem, presented by [22].

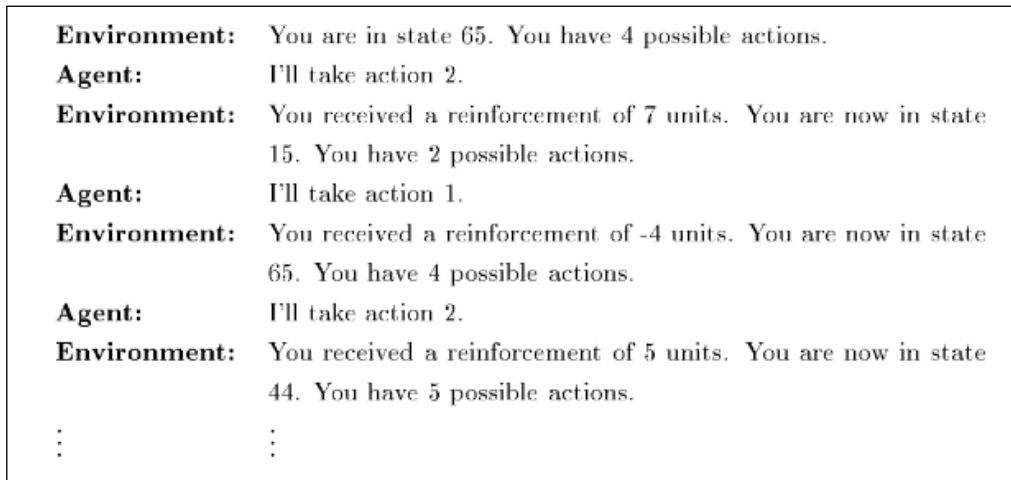


Figure 4: Reinforcement Learning Cycle.
Source: [20].

Figure 5 presents the general concept of the maze problem, which consists of making the robot (algorithm) reach the goal (gray ball). For this to happen, several phases will be covered, which will be explained below, containing related figures to facilitate understanding. On the other hand, Figure 6 shows the states of the environment, which represent the possible positions that the robot can assume. Figure 7 shows all possible movements for the robot to perform, which are moving up, right, down, and left

(North, East, South and West, respectively, meaning North, East, South and West).

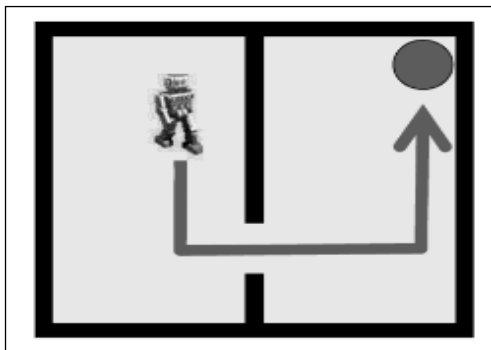


Figure 5: Maze problem.
Source: [22].

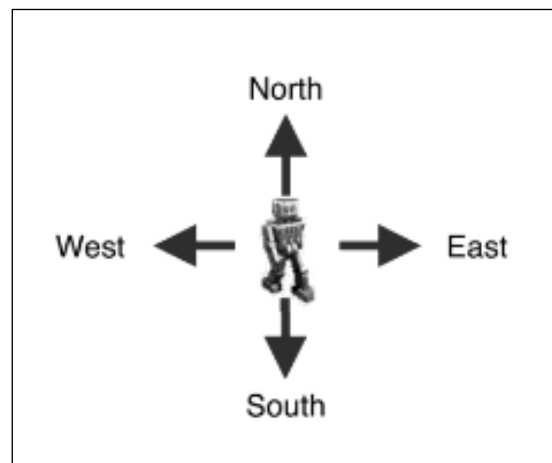


Figure 7: Possible robot movements.
Source: [22].

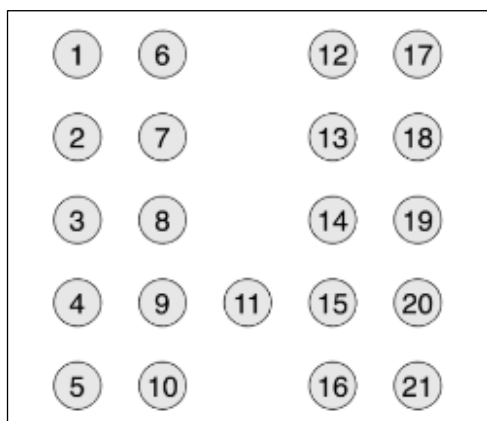


Figure 6: States of possible positions in the maze.
Source: [22].

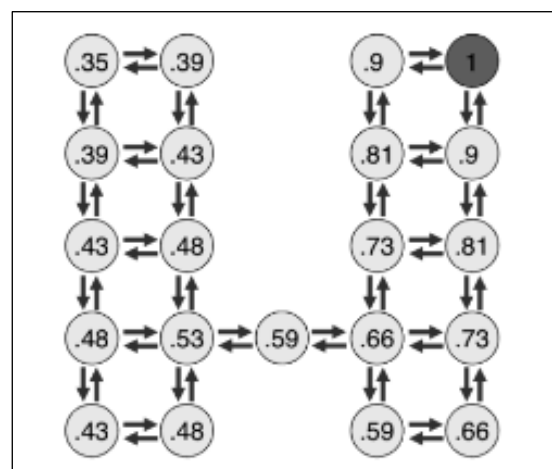


Figure 8: State transitions and rewards
Source: [22].

In Figure 8, the calculated reward values of each state are shown, which will then be used by the algorithm to decide the best action to take. One thing is important to note, that it does not matter if the path found by the algorithm is also the shortest, or the longest, but that it finds a path.

II.4.4.2 Use Case

A use case of this type of learning can be exemplified by the design of intelligent tutorials using Reinforcement Learning that assemble a dynamic and personalized study plan for each user, according to their history and performance [23].

II.4.4 Why was Android Chosen as the Target Operating System?

According to a survey by Bain & Company, 90% of smartphone users in Brazil use Android [24]. This is because Android is an open system, which allows the existence of several different brands using the system, and a variety of prices that gives accessibility to all social classes. Not only attracting users, but application developers also moved closer to Android, where for 83% of them, the fact that Android allows a highly collaborative ecosystem was the reason for the approach [24].

In the last decade, the number of users has only increased, starting at 26% and reaching an incredible 71% of users who had their first Internet experience through Android smartphones [24] (Figure 9).

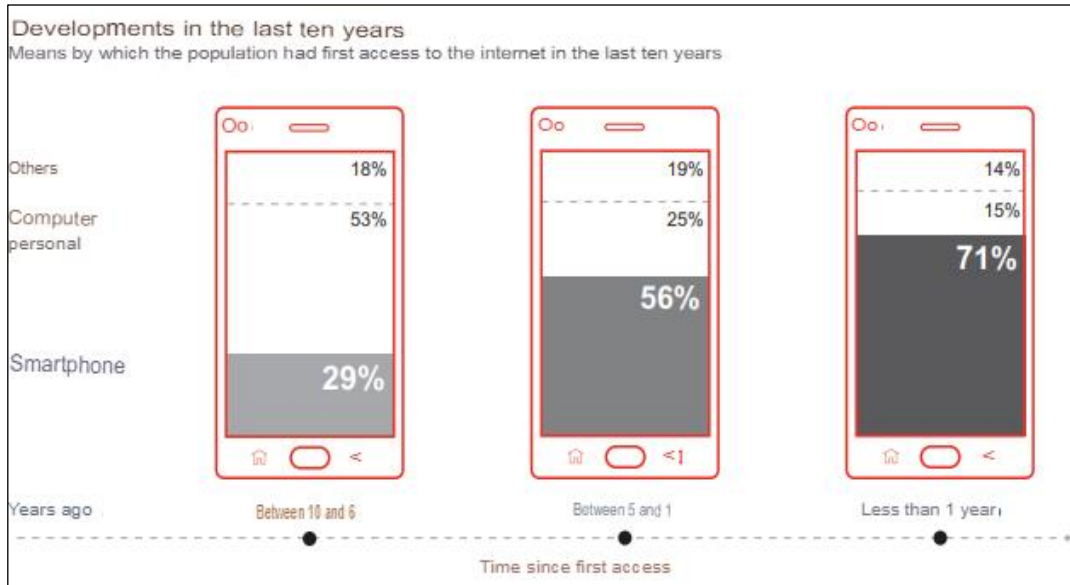


Figure 9: Internet access by Android device. Source: [24].

With these results, we can see the great influence that Android had and still has in the lives of Brazilians. With affordable prices, modern and pleasant designs, and an easy-to-use system, the mobile operating system is the most widespread and used in Brazil, making the choice of which system to use for the development of the application of this work very easy.

III. MATERIALS AND METHODS

This section will describe the materials and methods used to implement an automotive license plate recognition system. The system will be developed specifically for the use of the security secretariat of the city hall of the city of Manaus/AM. The development of the project is important considering that the fleet is increasing in the Amazonian capital, concentrating about 81% of the fleet registered in the state. To this end, an on-site visit to City Cooperation Center (CCC) will be carried out first.

Opened in 2020, the CCC is an operational and intelligent center for the city and its main objective is to integrate services from the main secretariats in one place, in addition to concentrating traffic monitoring information. He has been a great ally of the city of Manaus in situations of calamity in traffic.

The CCC uses a modern data center with a dual Dell-branded server to run the system, and for the monitoring of city streets, Motorola's AVIGILON software is used, capable of storing and identifying traffic signs and human faces.

Since it is in its initial phase, the CCC is being used more as an intelligence center for the DETRAN, where the guards send their photos, and they are analyzed by the technicians who verify if the fine is correct or not. The guards use WhatsApp to send the evidence of the fine to the technicians and the technicians, after verifying the fine, send it to PRODAM, responsible for the procedures for sending the fine to the citizen.

As of December 2021, there are 855,922 vehicles out of a total of 1,054,592 vehicles registered with the State Department of Transport (DETRAN-AM). The total is 4% higher than in 2020. The IBGE estimates a population of 2.2 million people, with one car for every 2.6 inhabitants. In the continental Amazon, the proportion is one registered vehicle for every 10 residents. According to the vehicle manager of DETRAN-AM, David Fernandes, internally, there are many vehicles in circulation that are not registered due to lack of inspection [25].

III.1 MATERIALS

III.1.1 Equipment Used

For the development of the application of this work, two notebooks will be used, whose technical specifications will be discussed in Table 1.

SETTINGS	
Laptop 1	Samsung (Expert X50, Intel Core i7-8565U CPU 1.80GHz 1.99 GHz, Memória RAM 20GB, NVIDIA GeForce MX110, 1TB (HDD) TOSHIBA MQ04ABF100 & 256GB (SSD) WDC WDS240G2G0B-00EPW0, Windows 10 Home Single Language 20H2)
Laptop 2	(Acer Aspire E 15, AMD Radeon R8 M445DX, 20GB RAM, 1TB (HDD), AMD Quad-core A10-9600p)

Table 1: Machine configuration.
Source: Authors, (2022).

III.1.2 Tools

In this section, the tools that will be used for the development of the license plate recognition application in this work will be discussed.

III.1.2.1 Figma

According to [26], Figma is a complete and easy-to-understand tool, whose simple and intuitive design allows the developer to easily build effective prototypes. The author also states that the tool is extremely practical, since it allows its use by the browser, without having to install the program on the computer.

In this way, Figma will be used to develop the layout and prototypes of the application screens, so that the application flows are planned, in addition to being possible to correct possible development bottlenecks throughout the process.

III.1.2.2 Android Studio

Android Studio is the official integrated development environment (IDE) for Android application development, built on IntelliJ IDEA, IDE for Java development [27]. According to the documentation, this tool also supports debugging, a tool that allows you to visualize the execution of specific lines of code in real time, offering a better visualization of logical problems, facilitating corrections.

In this work, this tool will be used to build the application, including the source code and visual interface of the application. In the development process, several libraries will be used to assist in the assembly of features, the main ones being discussed in the following topics.

III.1.2.3 Google ML Kit – Text Recognition

Google's library for using Machine Learning (ML) - Machine Learning - in mobile development, the Google ML Kit is the choice of every developer who needs a powerful and at the same time easy-to-implement solution [27]. According to the library's documentation, it presents several solutions that use ML, optimized for its implementation in both iOS and Android applications. All processing takes place on the device itself, making it fast and efficient, and allowing its use in offline environments. In addition, this library uses the technology that Google itself uses in its official applications, in addition to offering the developer easy-to-use APIs.

In this project, Text Recognition API (Text Recognition API) will be used. It allows recognizing texts of any Latin-based character set. According to its developers, it can also be used to automate data entry tasks like processing credit cards, receipts, and business cards.

For this work, it will be used to recognize the text of vehicle license plates, to facilitate users to send the license plate code more quickly and efficiently.

III.1.2.4 Hilt

According to [28], dependency injection is the process of efficiently building dependency graphs of other objects. According

to him, dependencies are nothing more than objects required by other objects for them to work correctly. For the injection to be performed correctly, [28] states that it is necessary to decouple the construction of these dependencies from the object that requires them, passing them through the constructor of this object in question. In this way, the main object becomes more flexible for testing, since you can pass the test version of each dependency informed, making it more flexible, in addition to facilitating its usability throughout the project.

In this work, the Hilt dependency injection library, developed by Google, will be used to perform this service of providing the necessary dependencies for the project to work correctly.

III.1.2.5 Data Binding

For [29] the definition of Data Binding can be understood as being a framework that helps in the synchronization of the visual interface with data models, presenting a real-time connection of the UI and Model. In other words, this tool allows the business logic to connect directly to the visual elements that represent the data of this logic, in a performative way, simple to maintain and easy to understand.

In this project, this resource will be used in the development of the application's screens and its business logic, to make the source code simpler, smaller, and focused on what really matters, leaving the repetitive and time-consuming work for the library, streamlining the application development.

III.1.2.6 Room Database

This library, developed by Google, was built to abstract many steps of the process of building, accessing, maintaining, and changing SQLite database (Android database) [30]. According to [30], Room uses methods in interfaces that the developer can use to perform different activities with the database, to summarize the repetitive logic (boilerplate) of database configuration.

For this work, this library will be used to store the inspections carried out by the user offline, so that at another time he can synchronize them with the server (in the prototype in an emulated way), giving him comfort and security when using the application. even without a stable or even non-existent internet connection at that moment.

III.1.2.6 CameraX

According to [31], the CameraX library facilitates the implementation of camera functionality natively to Android applications, being compatible with several devices and reducing the number of repeated codes (boilerplate code).

[32] states that the library has an API that abstracts the camera's functions, which allows its use in several Android devices, using the Use-case oriented paradigm.

Its use in this work will be to capture the image of the license plate so that the area of the license plate can be cut and soon after the license plate recognition by the ML Kit library.

III.2 METHODS

In this section, the methods that will be used to achieve the specific objectives defined in this work will be presented.

III.2.1 Study of Current Conditions

To understand the status of the current system, on-site visits will be carried out to obtain all the necessary information for the development of the prototype of the application of this work.

III.2.2 Determination of Integration Methods

The integration methodology will be defined as follows: the application system will simulate the integration with the CCC system, to perform all the actions that it would perform in the de facto integrated implementation, but with this connection being emulated for testing purposes.

III.2.3 Development of the System Prototype

The application system prototype will be developed in stages, described below:

First, the layouts of the screens and the application icon will be designed. Soon after, the application will be developed, starting with the screens designed in the first stage, and ending with its logical features.

At the end of the development, the project will enter the testing stage, starting with those of the developers and authors of this work, and then, when these tests are finished, continued through on-site tests by the transit agents selected later.

III.2.4 Analysis of the Prototype's Auxiliary Potential

The analysis of the potential to help traffic agents through the complete implementation of this prototype at another time will be as follows: after the tests that were carried out by the agents of the CCC (item III.2.3) are completed, will be collected feedback on the results of these tests, so that a case study can be carried out to identify the impact that a future integrated implementation of this project would have on the routine of transit agents.

IV. RESULTS AND DISCUSSIONS

IV.1 VISIT TO THE CITY COOPERATION CENTER (CCC)

To start the activities related to the development of an automotive license plate recognition system, a technical visit was made to CCC - Manaus, with the purpose of studying the current traffic inspection systems used by the county.

At the end of the visit, it was found that there would be no possibility of developing a system of size like the one used by the CCC and, therefore, it was decided to create a prototype that simulated the interactions of the traffic agents.

IV.2 DEFINITION OF INTEGRATION METHODS

After the visit carried out at the CCC, it was possible to determine the methods that would be used to perform the integration of the prototype user with the CCC system, in an emulated way. For this, the mandatory functionalities were defined so that, in a real implementation of the proposed system, the integration of both parts could be done without problems. The prototype functionalities decided by the authors of this work were:

- a) User's login
- b) Image capture
- c) Recognizer for text in images
- d) List of pending synchronization inspections

In this way, the integration methods were defined, and then the development of the prototype application of the solution system proposed by the authors of this work was started.

IV.3 DEVELOPMENT OF THE PROTOTYPE

IV.3.1 Application Planning

First, a name for the application was decided upon to give the project more personality. The name decided was *Agente Digital Amazonas*. The acronym of the application was determined as "ADAM".

After deciding on the name of the prototype, some sketches were made on paper of both the screens and the flows of the application, to plan, correct and improve the initial ideas about what the prototype would be able to allow the user to do, in according to your graphical interface. Subsequently, these sketches were digitally reconstructed for better visualization.

IV.3.2 Application Programming

IV.3.2.1 Database

To persistently save both login and inspection data, a database management library called Room was used. The used version of the library was 2.4.2. The application's database was structured by two tables, called *UserEntity* and *InspectionEntity*, responsible for storing user registration information and data from each inspection performed, respectively.

IV.3.2.2 Application Screens

IV.3.2.2.1 Splash

The first screen developed for the application was Splash. Splash screens have the function of presenting the application while the initial loading of the application is carried out. For the project, this screen has the function of simulating an initial synchronization of the application with the CCC database, to emulate the use of a real case.

IV.3.2.2.2 Login

The Login screen was then developed, which corresponds to the screen in which the unregistered user will perform the registration, to have access to the application's features. In this way, this screen is responsible for user authentication (main responsibility) and for accessing the screen for adding users to the database (prototypical responsibility, this screen would not exist in the actual implementation of the project).

IV.3.2.2.3 Main Menu

It is the prototype's main screen (Figure 10). In it, the user has access to the application's features, which are:

- a) View pending synchronization inspections.
- b) View history of inspections carried out (and synchronized).
- c) Start inspection process.



Figure 10: Main Menu Screen.
Source: Authors, (2022).

IV.3.2.2.4 Image Capture of the Vehicle License Plate

It is the screen responsible for capturing the image of the license plate to be analyzed later by the text-in-image detector (Figure 11).



Figure 11: Car Plate Image Capture Screen.
Source: Authors, (2022).

IV.3.2.2.5 Cutout of the Vehicle License Plate Area

Screen responsible for selecting the text area of the inspected license plate, as well as identifying the text and the user's current location (Figure 12).



Figure 12: Vehicle License Plate Area Cutout Screen.
Source: Authors, (2022).

For text identification, the text recognition library from Google ML Kit, Text Recognizer, is used, along with cleaning and correction techniques for the results obtained from the library.

The identification of the user's current location uses the device's Geocoder together with the latitude and longitude captured from the user's GPS.

IV.3.2.2.6 List of Inspections

Screen responsible for listing inspections performed by the user, whether pending or inspection history synchronized with the system.

IV.3.2.2.7 Inspection Details

Screen with the responsibility of handling the information of each inspection (Figure 13), allowing the user to edit this data in the context of pending, or send it to the server in the context of creation of inspections.

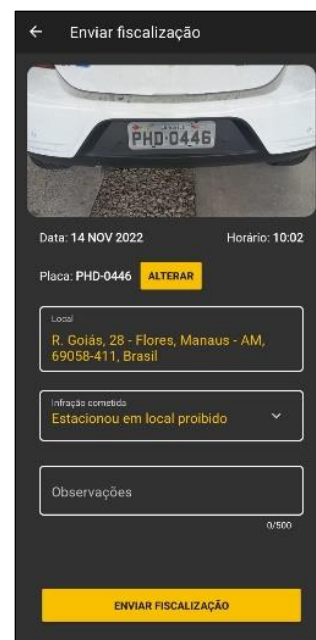


Figure 13: Inspection Details Screen.
Source: Authors, (2022).

IV.3.3 Tests

To attest to the functionality of the application, tests of its flows were carried out, with emphasis on the process of creating new inspections in the system. To achieve the results of the tests, it was necessary for the authors of this work to carry out field tests, capturing the images of the sample vehicle plates, so that the research findings could be recorded.

The prototype tests were divided into groups, following the conditions of distance and time of day tested. For example, one of the groups refers to the test performed in an average distance between the vehicle plate and the application, in the afternoon of the day. In this way, it was possible to observe the behavior and accuracy of the application in several different situations during the day.

Figure 14 below shows some of the results obtained in capturing the license plate image during the tests performed.



Figure 14: Application prototype tests' results.
Source: Authors, (2022).

V. CONCLUSIONS

This work intended to understand the development of a license plate recognition system in mobile devices to assist the inspection process of the traffic agents, from visits to the CCC, development of a prototype and field tests, verifying the possibility of adapting the existing system of paper inspections to the digital platform, increasing the effectiveness of traffic agents significantly, especially in regions with little technology, such as

the absence of 4K cameras for detection of infractions and recognition of license plates. In future research, the prototype can be integrated with PRODAM's system, and other aspects of this system can be analyzed, to improve the functionality of the application and present traffic agents with the solution they need in the palm of their hand.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Caio Augusto Barbosa Veras and Gabriel Melo Cavalcante.

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Investigation: Bruno Luís Litaiff Ramalho Júnior, Caio Augusto Barbosa Veras and Gabriel Melo Cavalcante.

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Resources: Alexandra Amaro de Lima.

Supervision: Alexandra Amaro de Lima.

Approval of the final text: Alexandra Amaro de Lima and Gabriel Melo Cavalcante.

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RESEARCH ARTICLE







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SCHOOL ATTENDANCE MANAGEMENT SYSTEM FOR STUDENTS THROUGH FACIAL RECOGNITION

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ABSTRACT

Currently, in the scenario of the city of Manaus, most of the records of attendance of students in educational institutions are made manually, thus making the process quite laborious and repetitive for teachers, added to this, this system does not present to be fully reliable, because the method used shows itself vulnerable to human error. To save time and ensure that the registration is done without any failure, this work develops and applies a system to register students using facial recognition, and also has a feature that triggers an email message warning the absence of the child to the parents responsible if the student is not present in class. The project uses the Ruby language, for the development of the attendance register management system, and the Python language in conjunction with the OpenCV library for facial recognition.



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I. INTRODUCTION

In the youth and adult learning process, the students' attendance in the classroom is an important factor in the evaluation of their school performance, since it is closely linked to learning, development of social and emotional skills, besides helping in a more assertive pedagogical monitoring and contribution of data for statistics [1]. Currently, the traditional process of recording students' attendance in educational institutions has proven to be flawed in terms of its reliability and efficiency.

The school attendance method most used by institutions is to obtain the signatures of students in class, but this method has a flaw that is the possibility of the student to sign by a classmate, and thus circumvent the method, causing the same failure of the traditional way [2]. But with the emergence of tools such as facial recognition, it is possible to visualize safer solutions. Currently, most smartphones unlock the device from the identification of the user's face as a way to provide more security in accessing the

device data. We know that facial recognition is not restricted only to mobile phone authentications but has also been expanding for other purposes [3]. Thus, we can use it in the school context, making it the most assertive option to solve the problem of academic records through an automated facial recognition system, thus saving teachers' time and avoiding incorrect attendance records.

The system of registering attendance of students came with the aim of checking and recording entry and exit of students through facial recognition at school and informing them through a message to the responsible, giving more security of who enters and who leaves. Its development is based on languages like *Python*, *Ruby on Rails*, *MVC* practice and theories such as notions of face and its symmetry, types of automated software testing and agile methodology.

This work is organized as follows: Section 2 discusses the main tools and concepts of symmetry and facial recognition, image processing and digital image used for the development of the

project; Section 3 presents the materials and methods adhered in the creation of the system; Section 4 describes the results and discussions obtained from the ready-made software; Section 5 presents the conclusion; Section 6 presents the acknowledgements; and, finally, in Section 7, the references are shown.

II. THEORETICAL REFERENCE

II.1 COMPUTATIONAL TOOLS

II.1.1 Python

Currently, the most popular programming language to develop tools in artificial intelligence has been Python, which stands out for its simple syntax and excellent readability [4]. Thus, the choice for this language was due to the previous reasons and to the diversity of libraries and packages available for the project development. According to [5], python is an open source and interpreted programming language and, for this reason, it provides a faster performance in the execution of programs, because it does not compile the algorithm.

II.1.2 OPENCV

In [6], the author defines the *Open Source Computer Vision Library* as a multiplatform library, i.e., it can be implemented and used on major platforms such as *Windows, Linux* and *Mac*, and it is completely free, to academic and commercial use, for the development of applications in the area of Computer Vision. In addition, it has a library composed by more than 500 algorithms developed in C/C++, highlighted in [7] where the authors present an abundance of documentation of this library, and this is due to its popularity in projects focused on Computer Vision.

II.1.3 Ruby on Rails

The *Ruby* language was created by Yukihiro "Matz" Matsumoto and had its first public release in 1995. While [8] defines it as a programming language with dynamic typing aimed at solving Web Development problems in a simple way, besides providing features aimed at developer productivity. The main objective of this article is to present a discussion of the main concepts and concepts of the Web development framework. This programming language can be used in word processing, game creation and, mainly with the resources provided by *Ruby on Rails*

framework, web development, being this last one the proposal we will use in this work. In short, *Ruby's* philosophy is: "Make simple things easy and complex things possible".

According to [9], *Ruby on Rails* is a *web* application development framework written in the Ruby programming language. This tool was designed to make programming easier in the niche of solutions it finds itself in, based on the assumptions most developers need to start a project, including support for databases and the MVC (*Model-View-Controller*) architecture pattern. Its premise is to write less code while accomplishing more tasks than many languages and frameworks.

II.1.4 Machine Learning and "DLIB" Tool

Due to advances in the area of artificial intelligence and computational systems, computers have been able to automate tasks that until now were only performed exclusively by humans. Early developments in this area depended exclusively on the ability of the researcher to encode the required knowledge into the algorithm itself. A more effective methodology was then developed, involving the provision of examples from which the computer can extract this knowledge. Such methodology is called machine learning. [10].

Dlib is a modern C++ toolkit that contains machine learning algorithms and tools for creating complex C++ software to solve real-world problems. It is used in industry and academia in a wide range of domains, including robotics, embedded devices, mobile phones, and large high-performance computing environments [11].

II.2 MVC

The MVC architecture pattern was developed in 1979 by Trygve Reenskaug under the name *thingmodel-view-editor*, and was intended to be used in conjunction with Smalltalk - 76, an object-oriented programming language that influenced languages such as Java and Objective-C. [12].

The basis of MVC is the separation of what is presented to the user through the Graphical User Interface (GUI) and the data manipulation of the system itself. This separation is performed through three components with direct interactions between them. The components are model (*model*), view (*view*) and controller (*controller*) [13].

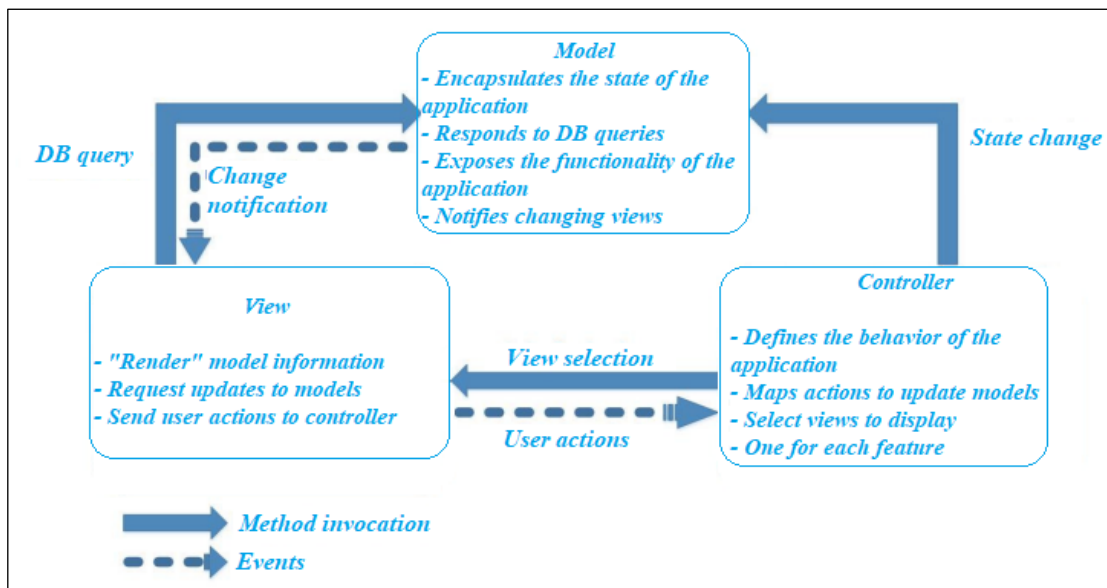


Figure 1: MVC Model.

Source: [14].

The model layer is responsible for encapsulating the data and functionality of the software. The component acts as a handler, intercepting all the operations involved in processing this data. This class of model is also known as domain; usually, the model has no idea about the user's interactions with the interface [15]. Still, the view component is responsible for displaying the information and deciding how this information will be displayed to the user [13].

The controller component is responsible for managing the interactions of the user with the interface, such as: key presses, mouse or interaction with the visible elements and passing the information to the view and the model so that the data are persisted [13]. Thus, MVC architecture assists developers in building applications by separating its main components, the data manipulation and storage, the functions that will work with the data inputs and the user view. The MVC architecture specifies where each type of logic should be located in the application [16].

II.3 AUTOMATED TESTS

Testing is an intrinsic practice to the development and is old, the need to create scripts or programs to test specific scenarios, especially for scenarios in which testing manually was impractical. However, using automated testing as a basic premise of development is a relatively recent phenomenon, beginning in the mid-1990s [17].

Currently, test automation is considered by several methodologies, especially among those identified with agile methods, as a basic practice to ensure the quality of a software. Much has been studied, new concepts and development techniques have been created and the tools are increasingly powerful and practical. All this facilitates not only the writing of tests for specific code snippets, but also for the integration of modules, graphical interfaces and databases [17].

According to ISTQB, testing is not just about executing tests and analyzing their results. This is a much more complex process that involves several steps such as test planning, analysis, design, test implementation, creating test progress reports, test results and analyzing the quality of a test object. It also involves reviewing the requirements and code. In addition to performing all this verification, this process also includes the validation of the system, ensuring that the system meets customer needs [18].

However, test automation reduces efforts in repetitive tasks, so not all tests should be automated. Before inserting this process in a project you should analyze what is the volume of tests that your software needs and the time that is spent to execute these batteries of tests. If the project in question has a very small complexity, the effort to insert this testing methodology can be more costly than the maintenance of manual testing. Added to that, the time to execute the automatic tests would not be, in this case, so less than the manual ones [19].

II.4 BASIC NOTIONS OF THE FACE

The face is the frontal part of the head, extending from the forehead to the chin, composed of the mouth, the nose, the eyes and the eyebrows. Through this set, they can convey emotions through expression, in which the individual is in his state of mind, that is, how the person feels at that moment [21].

II.4.1 Symmetry of the Face

When we talk about symmetry, immediately comes to mind the adjective of perfection, beauty, proportion, this because in the ancient age it was already sought symmetry through components

of harmonization of the physical lines of beauty in the faces considering them as beautiful.

According to the egregious theory of proportions inherited from the Roman architect Vitruvius, the proportional man has a face divided horizontally into three symmetrical parts [20]. The regions are classified as: mental, affective and instinctive [21].

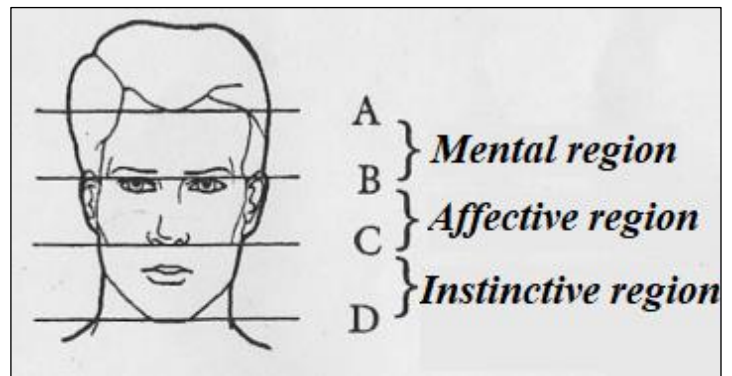


Figure 2: View of the three symmetrical parts of the human face. Source: [21].

AB mental region starts in the hair up to the eyebrows. Affective region BC starts at the eyebrows up to the nose aculeus.

The CD instinctive region starts at the aculeus of the nose and goes up to the chin.

According to the division, the width of the face should measure two-thirds of its length. The distance between the eyes should correspond exactly to the width of the nasal diameter, well aligned horizontally [22].

II.5 DIGITAL IMAGING

The image can be defined as a two-dimensional function, $f(x,y)$, where x and y are spatial coordinates (plane), and amplitude of f at any pair of coordinates (x,y) known as intensity or gray level of the image at that point. When x,y and the intensity values of f are finite and discrete quantities, called a digital image. Note that a digital image is composed of a finite number of elements, each with its specific value and location. These elements are called pictorial elements, elements that make up the image, pels and pixels. Pixels is the term called to represent an element of a digital image [23].

II.6 IMAGE PROCESSING

The processing of an image both input and output must be manipulated so that in the end it becomes an image, in the computational context this image is converted into data. After processing, these data are captured and subjected to techniques to obtain the variation of images that can be used in other processes [24].

Digital image processing goes through 3 levels up to computer vision, such as: low-level, medium-level and high-level [23]. According to [16], the low-level operates in noise reduction or improvement in image contrast. The mid-level is the segmentation or classification process. And finally, the high-level is the relation of the cognition task directly associated with human vision.

II.6.1 Biometrics

Every human being is composed of distinct characteristics such as: physical or behavioral that make them unique.

Identification through computer systems are means for automatic control of entry of reserved environments, records of activities, surveillance, etc., [25]. Therefore, biometrics is considered the science that measures the characteristics of each individual, classifying it as unique and exclusive through physical, chemical and behavioral attributes [26].

For [27] biometrics is divided into two categories, being the physical and behavioral category, which can be measured using different metrics. The first one fits, for example, in fingerprint, DNA's, face, etc. The second would refer to the psychological state, where, depending on the situation in which the person is, there would be a change in speech, walk, way of expressing and acting in general.

II.6.2 Facial Recognition

The face recognition system is a biometric that uses the face of a person through a detection equipment and compares it with an image (photo) stored in a database. This comparison is made using the detection and adjustment of high points, low points and the contour present on the face [40].

Face recognition is the process of recognizing and naming (labeling) a face. [29]. This process is a computational resource that recognizes the face and transforms it into an image.

The facial recognition uses a set of images that have been collected in a certain time, with this facilitating in the search for characteristics of the face and distinguishing it in relation to the rest of the environment, these facial photographs have to be contained in official documents, making it authentic and decreasing the invasion, making it cheaper to obtain the images. [30]. However, it can present as a disadvantage the possibility of suffering interference in its operation, due to the conditions of the environment, such as lighting, and people, such as: position of the individual, age and emotional state; with this increases the level of difficulty of implementation [31].

II.7 AGILE METHODOLOGIES

A group of seventeen *software* specialists in 2001, were discussing ways to improve the performance of their projects, presenting several agile methods as options for their software, thus was born there the term called "Agile Methodology". In this meeting they observed in their previous experiences that there was a set of common principles, that when followed their projects worked well. Thus emerged the agile alliance that established the agile Manifesto where it brought its values, its philosophy and its principles.

Agile methods are a set of practices that follow the principles of the Agile Manifesto [32]. The agile manifesto is not against traditional models [33]. Agile methods are based on incremental development [13], which contains techniques used in software engineering. However, its pattern is not proposed by traditional methodology [34].

Agile methodologies use new class of methodology developed to meet the growing market demand through more agile and light processes in increasingly shorter development cycles [35]. These methodologies are focused on individuals and the interaction between them, on the functioning of the software, on the interactivity with the customer and with fast response to changes. In this way, it is possible to be more agile by adapting the requirements with short-term delivery objectives by the time it enters the development phase [15].

An important feature found in all Agile Methods is the recognition of *software* development as a process based on experience and observation [36].

Some more used agile methodology that has the collaboration of the client and the rapid response to change and amendments, because besides having common base of their conceptions, with engineering and management, their results are satisfactory when applied, they are them: *Scrum*, *Extreme Programming* and the *Lean Software Development* [37].

II.7.1 Extreme Programming

Extreme Programming (XP) is an agile methodology for small and medium teams that develop *software* based on vague requirements and that change quickly [38]. It is a software development methodology to meet the need of customers through its speed, productivity and quality in a simple way. It is a methodology for the development, where the requirements are constantly changing [39].

III. MATERIALS AND METHODS

III.1 MATERIALS

To develop the computational solution of the problem raised in the research, various computers were used. The list of materials and peripherals that we used in the development of this project, are presented in Table 1, presented below.

Table 1: List of peripherals used.

<i>PCs</i>	<i>Laptops</i>
Processor: <i>Intel I5 9400f</i> ; Dedicated video card: <i>GTX 1650</i> , Primary Memory: <i>Asgard RGB 16GB(2 x 8GB dual-channel)</i> DDR4 and frequency 2666mhz; Operating System: <i>Windows 10 Pro</i>	Processor: <i>Intel i7 11th</i> generation; Primary Memory: 8GB; Secondary Memory: <i>SSD 250GB</i> ; Operating System: <i>Linux Ubuntu 20.04 LTS</i> ; Model: <i>Dell vostro 15 3500</i>
Processor: <i>Ryzen 7 3700x</i> ; Dedicated video card: <i>XFx QIck RADEON RX 6600XT</i> ; Primary Memory: <i>Asgard RGB 16GB(2 x 8GB dual-channel)</i> DDR4 and 3200mhz frequency; Secondary Memory: <i>Kingston 1 Terabyte capacity NVME M.2 SSD</i> ; Operating System: <i>Linux Kernel, Fedora 36</i> distribution	

Source: Authors, (2022).

A *Webcam* embedded in each notebook was used as a testing parameter in facial recognition. In the case of *PCs*, we used a dedicated device and a *smartphone*.

Dedicated *Webcam*: *ASHU H701*, Full HD resolution and video capture up to 30 frames per second.

III.2 METHODS

III.2.1 Development Project

The project consists of two applications communicating through *HTTP* requests. Thus, it was possible to obtain scenarios for each type of applicability under development. First, it was necessary to include a *web* solution to store the information of each student such as: registration number, name, enrollment number, identifier (CPF or RG), series, class and shift, besides having a photo gallery of the student in different positions. Furthermore, the

system will send notification to the parents or guardians of each student, which means that the parents' information, such as e-mail, will also be stored. In this scenario, a modern software development solution with *Ruby* programming language was used. To adhere to the best practices of *web* development in *Ruby on Rails*, the code followed "The Rails Way" principles, this went beyond its philosophy of "Don't Repeat Yourself (DRY) and Convention Over Configuration".

The paradigm is Object Oriented and with an *MVC* design pattern, moreover, it is strongly recommended by the community to use automated tests. It is possible to add *gems* to projects, which are resources that allow a more pragmatic development, since simplicity is the main focus of the *Ruby* ecosystem. With this, we design a modern Web application without worrying about major bureaucracies, as a counterpoint to classic languages. In the context of automated testing, for example, we use *RSpec* that validates the system units, as well as the functional requirements and if the system as a whole meets what is proposed.

Finally, the context of greatest value of the system, is the service written in *Python* with the popular tool *OpenCV*. The **open source Computer Vision Library** accumulates several algorithms for **Computer Vision**. Essentially, it is an **API** written in *C++*, and can be used in specific purpose projects with programming languages like *Python*, *Java*, among others.

There are several solutions for *OpenCV*, they are: facial recognition, automated inspection and surveillance, counting the number of people (pedestrian traffic in a *mall*, etc.), defect detection in the manufacturing process, object recognition, medical image analysis, among several other applications. For the purpose of this project, this tool is of paramount importance in facial recognition of each student, since its responsibility is to detect and send data to a *web* application, i.e., based on a battery of registered photos of the student, the system will be able to validate the personal integrity to assume the authentication of the student in the classroom.

Based on the modularization that the tool has, we used to make the development of the second application simpler. With this, we obtained two applications communicating with each other, on the managerial side, a platform written with *Ruby On Rails* that uses a more active and visible context service to the students that will be developed in *Python* and *OpenCV*, being each tool responsible for a solution of our research.

III.2.2 Project Infrastructure

In the context of a team product development, it is of utmost importance that the main tools used are shared among each team member, so that the workflow is efficient. Considering the need for versioning, the source code was hosted on the *GitHub* platform, which according to its own documentation, is defined by offering free and paid products aiming to store and collaborate on the developers' code. With this we used two repositories, one for each research application, being the student attendance management system and the facial recognition service.

Some resources of *software* methodology were fundamental to ensure the security of a new implementation, we emphasize in certain essential aspects: At each *commit* to the remote repository the Automated Tests and security validations must be performed. Once properly validated.

With this routine from the development members, we schematize the *CI* of the project. Detailing the tools, *GitHub* goes beyond hosting and versioning source code. One Continuous Integration automation tool for *Ruby* is *RubyCI*, providing a simple setup for the community and delivering features specific to the best practices of an efficient *Rails* infrastructure. This allowed us to configure security executors and automated tests for the student attendance management system repository. It is worth noting that we will be using a relational database with *PostgreSQL* as the *DBMS*.

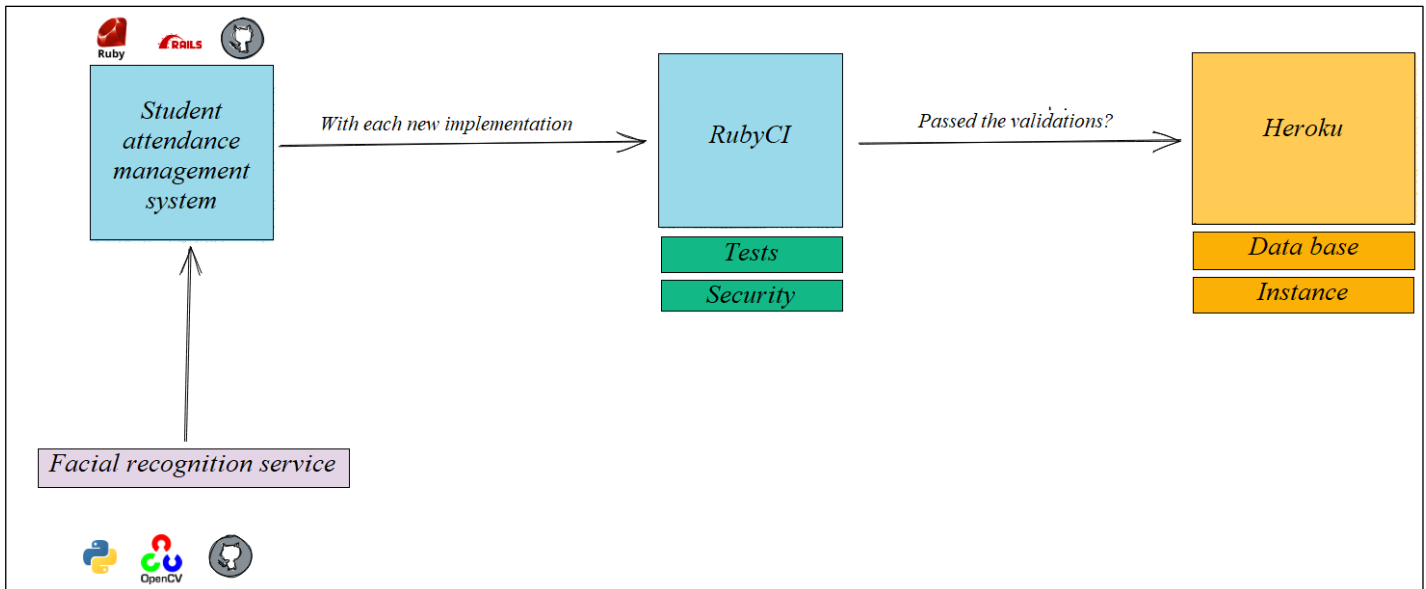


Figure 3: Project development flow.
Source: Authors (2022).

III.2.3 Agile Methodology

We used the *XP* agile methodology to have a more assertive, simplified and fluid approach in the project development activities. During the development, small tasks were made so that the junction

of them will result in the complete system. This approach, that is, the creation of small tasks, is known as "divide and conquer", widely used in the *Extreme Programming* methodology. Thus, we held weekly meetings to discuss possible solutions to the activities

created and ensure the general understanding regarding the product.

IV. RESULTS AND DISCUSSIONS

Initially, an *online* survey was raised directed to education professionals working in the city of Manaus. It was obtained in total 21 responses, indicating the type of institution and performance coming from each interviewee, among other data relating to the educational context. It is noted that 55% of professionals in the area of education who responded to the survey are from public institutions, while 45% of them were from private schools or universities. Furthermore, experience in modalities were recorded: face-to-face, hybrid and distance learning. However, Figure 4 demonstrates what the small shows the approach used in the task of recording the students' attendance, where, in some cases, it is possible to note the exclusive applicability of the manual form.

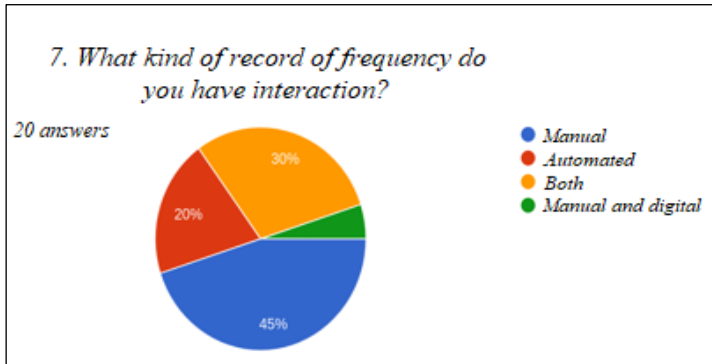


Figure 4: Type of Frequency Record Used. Source: Authors (2022).

IV.1 FACIAL RECOGNITION

The facial recognition application is a dependency of the system, so its only functionality is to receive, process and return

data. We adopted a library called "face_recognition", which has all the necessary requirements to achieve the goal of recording student attendance. In Figure 4 we have an example of its functionality with a face that identifies itself as "Yves". In this case, we used an input data (Photo of "Yves"), which processes the recognition from the sent photo, associating it with its respective identifying name. The output showed that "Yves" was identified, even if using mask.

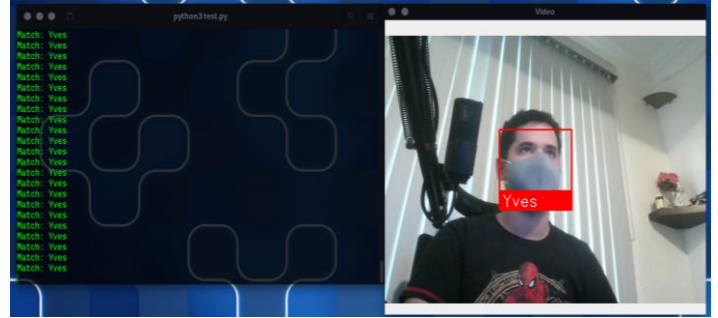


Figure 4: Example of Face Recognition. Source: Authors (2022)

IV.1.1 Modeling the System

First, the models *Student*, *SchoolClass*, *Responsible*, *FrequencyRegister* and *Register* were created. Furthermore, the cardinality was designed with the following logic:

- A *SchoolClass* can have many *Students*
- A *Student* may have only one *SchoolClass*
- A *Student* can have only one *Responsible*
- A *Responsible Party* may be responsible for several *Students*
- A *SchoolClass* can have many *FrequencyRegisters*
- A *FrequencyRegister* is related to a *SchoolClass*
- One *FrequencyRegister* can Register many *Students*
- *Students* may be present in multiple *FrequencyRegisters*

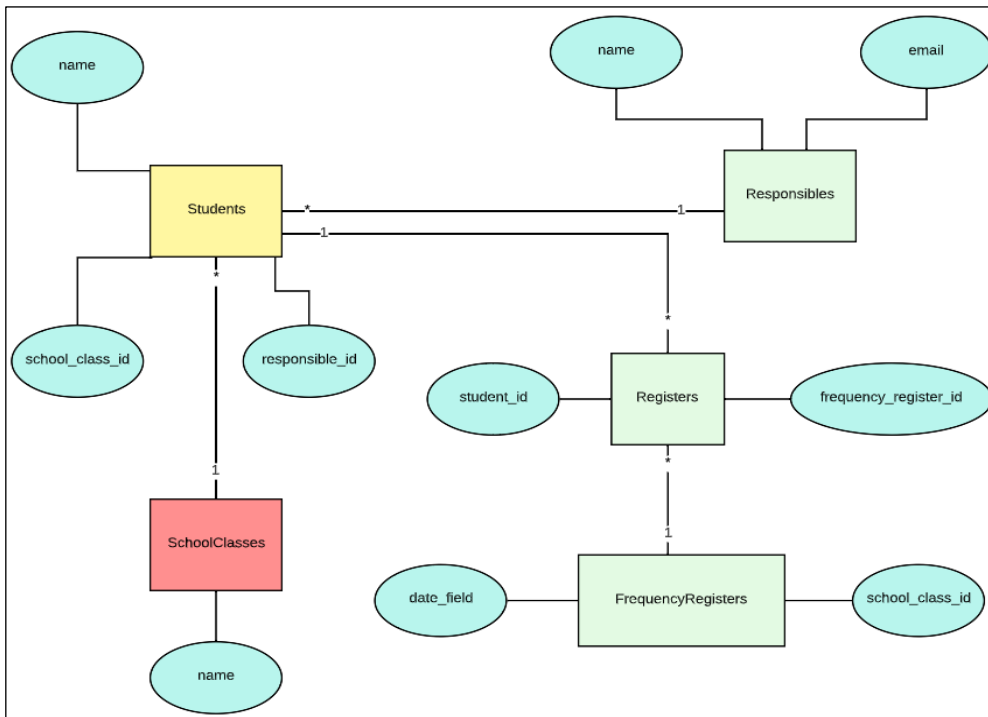


Figure 5: Data Modeling. Source: Authors (2022).

IV.2 PROTOTYPE SYSTEM

Figure 6 shows the initial screen of the system, where you can see the name of the application, a short description and a navigation menu for the main "Roles" of interaction. Each section lists the records of the related Object, i.e., by clicking on "Students", we have as a response a catalog of students of the application, the same idea applies to the others. Another point is the functionality to create a new resource, present on all pages in a manner adapted to each context, for example, in the "Responsible" page is noticeable a button to create a Responsible.

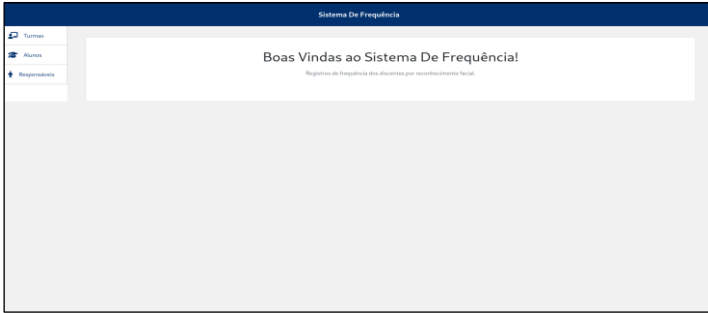


Figure 6: System Home Page.
Source: Authors (2022).

To reproduce a real scenario of the system's applicability, you must first register a Class by clicking on "Create a Class" and writing its name, for example, "Computer Science". Then, the next step is to register a responsible person, identifying him as "Yves César" and e-mail "yves_responsavel@gmail.com".

Therefore, the process of registering a student is initiated. The requirements of a student is:

- Standardized 3x4 photo, with good lighting and focus on the face.
- Name I.D.
- A responsible one.
- A class.

In this case, you can create a student with the name "Lais Reis" being the responsibility of "Yves César" and participant of the class "Computer Science". Once your registration is complete, you can start. Clicking on "Create a record of attendance", the computer camera is triggered to perform facial recognition, in this example is notable the identification of the student Lais Reis and its respective ID.

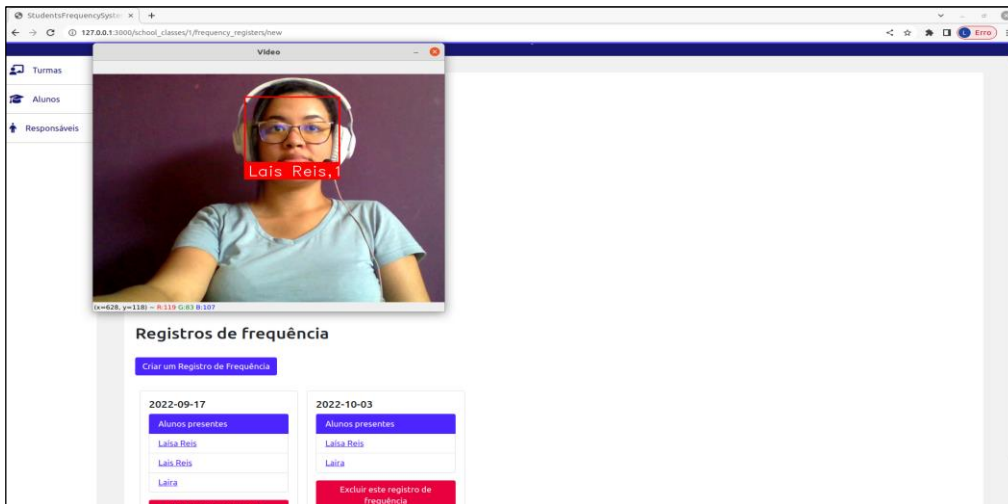


Figure 7: "Lais" Identified.
Source: Authors (2022).

By pressing the "q" key to finish running the attendance register, you can view the list of students present and a Date. By

adding this record, all the students' guardians will be notified via email about the presence in the class.

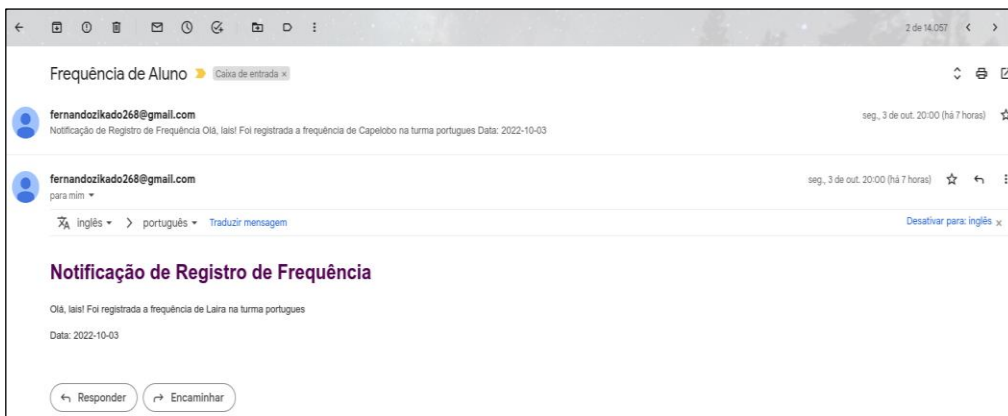


Figure 8: Frequency Notification.
Source: Authors (2022).

V. CONCLUSION

With the data survey on how schools or colleges of Manaus register their students' attendance, it can be observed that we still have failures of security and productivity of students and teachers. Among the interviewees' reports, it is generally used the traditional approach, recording manually, as well as, having the help of a system for registration. However, this model can still be problematic due to erasures, forgery of signatures or too much energy expenditure of those involved with this type of activity.

Facial Recognition is a very significant help regarding the issue of student safety, because identifying via camera the tendency is that this flow is more accurate and less bureaucratic. Moreover, it becomes possible to give the fastest *feedback* to the responsible of the student, and less energy expenditure of teachers and propensity to human error. As a limit of this project, we can highlight that the face detection tool needs standardized photos and with good lighting, so that the algorithm can in fact map the face, another problem could be the issue of twin brothers having similar traits.

In the development process, it was possible to maintain the good modern testing practices, making it safer to add each implementation in the project without losing the integrity of the functional requirements. Thinking in *Extreme Programming*, it was possible to have a more agile coding, aiming, at each *Feature*, what would bring greater value to the project in a simple way. The *Ruby On Rails Framework* was of paramount importance in terms of productivity and alignment of the methodology used, due to its ideology of making coding more objective.

Thus, the system of registering students' attendance with facial recognition was suggested as a prototype to solve the problem raised in the research, listing the identified students and notifying parents or guardians, besides providing the necessary functionality to create, edit and delete data in each part involved in the application.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Yves César Amorim de Azevedo, Laís Reis de Jesus, Wilson Fogaça de Araújo and Fernando Filipe Da Silva Costa.

Methodology: Yves César Amorim de Azevedo, Laís Reis de Jesus, Wilson Fogaça de Araújo, Fernando Filipe Da Silva Costa and Alexandra Amaro de Lima.

Investigation: Yves César Amorim de Azevedo, Laís Reis de Jesus, Wilson Fogaça de Araújo and Fernando Filipe Da Silva Costa.

Discussion of results: Yves César Amorim de Azevedo, Laís Reis de Jesus, Wilson Fogaça de Araújo and Fernando Filipe Da Silva Costa.

Writing – Original Draft: Yves César Amorim de Azevedo, Laís Reis de Jesus, Wilson Fogaça de Araújo and Fernando Filipe Da Silva Costa.

Writing – Review and Editing: Eliton Smith and Alexandra Amaro de Lima.

Resources: Eliton Smith and Alexandra Amaro de Lima.

Supervision: Alexandra Amaro de Lima.

Approval of the final text: Yves César Amorim de Azevedo, Laís Reis de Jesus, Wilson Fogaça de Araújo, Fernando Filipe Da Silva Costa, Eliton Smith and Alexandra Amaro de Lima.

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RESEARCH ARTICLE

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ELECTRONIC TIME CLOCK: DEVELOPMENT OF A FACIAL RECOGNITION SYSTEM TO CONTROL THE I.T. TRAINEES AT SEJUSC

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ABSTRACT

The article reports the development of an electronic time clock with facial recognition aimed at Information Technology trainees of the State Department of Justice, Human Rights and Citizenship. This is a device in which it is possible to register the clock-in and clock-out schedules, and in addition, it is possible to check the overtime report where the sector supervisor can offer these hours as days off. Given the deficiencies found in the sector, one being the frequency control that was still being done manually and the other, the high demand for work with the need to work overtime, the theme was developed. The importance of the system is that it makes the dynamics of the working day more automated and optimized. In its creation, the methodology of research, interviews, and data collection was adopted, as well as technological tools such as Biometrics, Programming Language, and Database. After the development and tests, it was possible to implement the electronic time clock in the sector. It was found that with low cost technologies available and with the ease of access to information it was possible to solve the problems of the sector of an organization.



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I. INTRODUCTION

The Department of State for Justice, Human Rights and Citizenship (SEJUSC) is composed of many sectors, among them the Information Technology Management (ITM) that is responsible for technological resources. And this sector is outdated regarding the frequency control since it is still done manually. Moreover, on certain days, there is a high demand for services with the need to work overtime.

Most employees of the ITM are trainees and according to current labor laws they cannot receive payment for overtime. Given these facts, we have the following question: would combining facial biometrics with the idea of an electronic timecard that sends the amount of days off make the sector's attendance system optimized and secure?

With the development of technology and ease of access to knowledge, it has become possible to develop electronic systems

that meet certain needs. Therefore, using python language with facial biometrics it was possible, through a webcam, to recognize a person's face. This way, the goal of this work was to develop an electronic time clock with facial recognition for trainees of the ITM of SEJUSC.

This work aims to develop a low cost system, to help the sector, where the supervisor, with the overtime bank, can offer the correct amount of days off to the trainee and, thus, optimizing and automating the work in the sector.

Analyzing the sector's demand, as well as the trainees' work dynamics, was the first step taken as a methodology, then creating the layout of the electronic time clock system, to develop the frequency system and the information database, and testing the system by creating a library of the trainees' faces.

This work has the following structure: section II explains the theoretical framework in which facial biometrics, python language, clock-in and database are based; section III explains the

materials and methods for the development of the slack system; section IV shows the results and discussions; section V concludes with the results obtained with the development of the project.

II. THEORETICAL REFERENCE

To develop the proposed solution, it is necessary to study biometrics for facial recognition, python language for programming using its OpenCV library, database to store and organize the information, and the notion of time clocking and attendance control. These topics are discussed in the following sections.

II.1 BIOMETRY

Biometrics have the function of recognizing behavioral patterns or physical characteristics to assess a person's authenticity. In general, these systems are suitable for situations where you want to monitor logical or physical access to an environment, attest to attendance at appointments, establish location monitoring, or ensure the practice of law [1].

Biometrics is a field of study that uses statistical and quantitative analysis to identify human characteristics that are unique to each person. Currently, this area has been related to biometrics, which is the provision of materials through the recognition of measurements and structures of organs capable of distinguishing people [2].

According to [3], the most popular solutions that solve the problem of facial recognition are based on the location and analysis of facial attributes such as nose, eyes, or the overall analysis of the face. The basic flow of facial biometrics systems has four basic steps, they are:

1. Face detection in image or video;
2. Location of the face in the image;
3. Extraction of facial features (nose, mouth, eyes position) and comparison with knowledge base;
4. Return the stored pattern closest to the biometric signature pattern of the input image.

II.2 BIOMETRIC SYSTEM

According to [4], the role of a biometric system is to obtain biometric data from users, extract a specific set of features from that data, and then compare them with pre-registered templates in the database which can be characterized as a pattern recognition system.

According to [5], biometric systems are characterized by the integration of devices, programs, and algorithms in order to compare the characteristics of individuals so that it can be determined whether they belong to the same individual. They also add that in order to obtain results, some steps are important.

- Acquisition: The application digitally captures an individual's biometrics;
- Segmentation: the step of separating the information from biometrics only;
- Quality assessment: assurance that the information obtained is sufficient or correct;
- Enhancement: steps to improve sample quality;
- Feature extraction: salient features are then collected and stored in the model;
- Matching: The collected model is then compared with previously stored models to determine if the feature belongs to the individual being analyzed.

II.3 FACE RECOGNITION

Facial recognition, a skill we use every day in our lives, is the human cognitive trait that developers take inspiration from in the search for something that can process digital images automatically. Facial Recognition technology involves various automated processes in which digital facial representations are used to attempt to identify or verify the identity of individuals [6].

The face recognition process can encompass numerous parts [6]. Capture and detection are related to the acquisition of images or photographs. Captured situations can be: authentication to reach the tool or service; in a controlled environment; voluntary or not; and image collections available on social networks. Registration, on the other hand, is the method of collecting visual information from individuals to form a set or database [6].

The data collected in the previous steps is then processed using a face recognition algorithm. Traditionally, recognition algorithms can be divided into geometric methods relating to photometric or salient features, allowing classification between holistic algorithms - those that seek to fully recognize faces - and feature-based methods - methods that analyze local facial features and store parameters and metrics, e.g., angles and distances between facial features are used as descriptors for comparison in future face identification processes [7].

II.4 PYTHON LANGUAGE

Introduced in 1991 by Guido van Rossum, it is a free language (even suitable for commercial projects), and today can be programmed for desktop, web, and mobile devices [8].

The [9] also talks about its main features, which include: ease of use, through elegant syntax and easier prototype programming;

A wide variety of libraries that support most programming-related tasks; do not use special character types at the end of each line of related code, such as ";" (semicolon), which is common in other languages; also support many types of programming paradigms, such as object and aspect oriented, functional, imperative, and reflexive [10]. After all, it is an open-source language and not exclusive to a single operating system.

II.5 OPEN-SOURCE COMPUTER VISION LIBRARY (OPENCV)

Among all alternative methods of biometric identification, face biometric identification is the most prominent [11]. This is because face recognition requires less contact between the individual and the device receiving the biometric information, compared to other biometric features (iris, fingerprints, etc.), and has a low cost of installation and supervision, which basically requires a camera and a server running an application programming interface (API) for face recognition.

Among the APIs ready on the market, the Open-Source Computer Vision Library (OpenCV) stands out, a free and open-source library containing a large number of means for designing computer vision practices [12]. Developed by Intel, the OpenCV library has over 500 features covering multiple spheres of computer vision [13]. Containing interfaces in C++, Python, and Java languages, OpenCV supports operating systems such as Mac OS, Windows, Android, Linux, and iOS.

According to [14], one of the purposes of OpenCV is to provide easy-to-use computer vision support in order to help people quickly produce complex computer vision applications. The OpenCV library is used in different parts of the world and has a

pool of over 47,000 users with a download count of over 14 million [12]. From the moment it was released in 1999, the OpenCV library has been employed in many applications, products, and studies. These features cover automatic surveillance of security systems, distortion reduction of medical images, camera calibration, etc.

II.6 DATABASE

Databases can be defined as collections of integrated data. Data are facts that can be registered and that have an implicit meaning, for example: names, phone numbers and as addresses that are stored in phone books or on computers through spreadsheets. This information is a collection of data and consequently, a database [15].

A database relationship is an association between tables created using a join statement to retrieve data. In the relational model, there are three types of associations between different entities (tables). These relationships are used to map how tables interact and can be categorized in three ways: 1-1 (one to one), 1-N (one to many), and N-N (many to many) [16].

II.7 USING FACIAL BIOMETRICS TO CONTROL TIME CLOCKING RECORDS

By controlling the working hours of company employees, usually done manually through a time book, authorized by the Ministry of Labor, through Ordinance No. 373/2011, using computers to mark time, organizations are able to condition this procedure and suppress points of failure. According to [17], "This is marked by the use of technologies such as fingerprints (biometrics), as computer systems are used in many companies".

Time and attendance or time control is the act of recording employees' clock-in and clock-out schedules at their place of work. Time control occurred in several ways over the years, from the constant viewing and recording by an employee of other people's action times, to notes made by the worker himself, in a book, where he registered his entry and exit, clocks, watches, cards, which make room for technological innovations, allowing changes such as biometric clocks and time stamps made by cell phones or computers [17].

The use of biometrics is the prerogative of large companies, but this reality is changing very dynamically. Small businesses and homes are already using this technology in order to increase security and prevent theft, fraud and other forms of attack. The adoption of these systems helps to increase the authenticity of individuals and increase the security of computer networks [18].

III. MATERIALS AND METHODS

Applied research is concerned with the application, use and practical consequences of knowledge. It aims to apply scientific knowledge to solve a wide variety of individual or collective problems. It is accomplished by means of "applied sciences" and "technological sciences" [19].

Regarding the research methods used in this work, in search of a solution to the problem presented as a referential framework,

it can be said that it was an applied research work in order to generate sufficient knowledge about the subject, with the interest of contributing with a practical application, capable of supplying the central question.

The materials used in making the facial recognition device project are Notebook, Webcam, Astah Community, PyCharm IDE (version 2020.2), MySQL DBMS.

The methodology used for this project in the first place was to collect the necessary field data, in this case, to capture the images, and also to verify how the frequency structure was until the moment of this research. In addition, the survey of theoretical material in websites, books, academic articles, etc., and consequently the choice of the necessary tools, that is, the use of programs and specific language for programming the software.

IV. RESULTS AND DISCUSSIONS

From this chapter, the results obtained in the development of the electronic time clocking system will be discussed, which shows the amount of overtime for the administrator, the manager of the ITM, the amount of overtime that the trainee has to be converted into days off, so called slack time.

IV.1 ANALYSIS OF THE DYNAMICS OF THE INTERNS' WORKING HOURS IN THE ITM SECTOR

In the requirements acquisition phase meetings and interviews were held with the help of the manager, where the working hours at the ITM were analyzed. The department consists of registered employees on business hours from Monday to Friday, i.e. 8 hours a day, with a lunch break between 12:00 and 13:00. However, for the trainees, the schedule is 6 hours a day, therefore allocated in two shifts: 8am - 2pm and 11am - 5pm, thus configuring two shifts, morning and afternoon, respectively.

The manager mentioned during the meetings that ITM serves several departments in different areas of the city of Manaus and also some cities in the interior of the state of Amazonas. On some days, the demand for work is quite high and overtime is needed. However, there is a problem, because according to the current labor laws, trainees cannot receive payment for overtime.

As a solution to the problem, he suggested to the trainees to work overtime under the following conditions: 6 hours of work plus 1 extra hour maximum. And as a bonus, the individual who agreed with the idea would be given 1 day off, that is, if you worked 1 hour overtime you would get a day off. However, there is a deficit in this solution, because the manager would be losing 5 hours of work for every 1 extra hour worked.

In addition to this problem, the attendance register is done manually. For example, a trainee in the morning, the registration form is filled out as follows: check in at 8am and sign; check out at 2pm and sign. Thus, configuring it as a British record. However, this does not happen in reality, because no one keeps this attendance with such accuracy and fidelity.

Below, in Figure 1, we have the monthly attendance register template to be filled in, for the month of August in the year 2022.

The form is titled 'FREQUÊNCIA MENSAL' and is for the month of 'AGOSTO' in the year '2022'. It includes fields for 'DEPARTAMENTO/SETOR', 'GTI', 'MATRÍCULA', 'CARGO', 'ESTAGIÁRIO', 'FUNÇÃO', and 'ESTAGIÁRIO'. The main table has columns for 'MÁTUTINO' and 'VESPERTINO', each with 'HORA ENTRADA', 'ASSINATURA', and 'HORA SAÍDA'. The dates from 1 to 31 are listed in the first column, with alternating days marked as 'SÁBADO' and 'DOMINGO'. At the bottom, there are fields for 'ASSINATURA /CARIMBO DA CHEFIA Imediata', 'NOME', and 'CARGO'. The logo of the 'Secretaria de Justiça, Direitos Humanos e Cidadania' is also present.

Figure 1: Attendance record sheet.
Source: [20].

In a second technical visit, it was necessary to collect the name, work registration, e-mail, date of birth, gender and shift of the trainees to put into practice the work proposal, however, as a form of security, the personal data were not disclosed in this monograph. The tests performed with the device created and presented in this document were tested with the authors' data, and also, each one received a pseudonym: user 1 (Sildoney), user 2 (Adison) and user 3 (Jussara).

IV.1.1 Specifying Software Requirements

Finalizing this first stage, the Software Requirements Specification document was created. This document contains product information such as the needs, mission, limits, benefits, definitions, and acronyms. These can be seen in Chart 2 below.

Table 1: Software Requirements Specification.

1 Objectives of this document		
The purpose of this document is to describe the specifications of the electronic time clocking registration needs for trainees of the ITM sector of SEJUSC, which will use the concept of Facial Recognition to perform the registration, as well as to present a report of bank of hours for use in time off.		
Target audience: customer, users, and developers.		
2 Product scope		
2.1 Product Mission		
The mission of the Electronic Time Clocking System with Facial recognition is to contribute to the improvement of the registration control of the exceeding hours worked in the trainees' day, in order to inform a monthly report of hours to be used for assisted leaves.		
2.2 Product limits		
1	The system will not be effective in low-light environments	
2	For efficiency, the System will require the user to position the face so that it is free of sunglasses, masks, and caps or hats.	
3	For each Trainee, several photos in different positions will be required to be registered in the facial recognition system (registration of 100 to 400 frames from various positions of the face).	
4	The photo registration environment should have a standard lighting for all photos.	
5	The System is totally dependent on the electrical energy of the applied environment.	
6	The good functioning of the system depends on the seriousness and responsibility of the people in charge of the sector.	
7	For each registration made by the user through facial recognition, a proof of entry or exit will be sent via <i>email</i> .	
2.3 Product Benefits		
Order Number	Benefit	Customer Value
1	User identification through Facial Recognition for entry and exit registration.	Essential
2	Sending a proof of registration via <i>email</i> , stating the exact date and time.	Essential
3	Allow the supervisor to have full access to the trainee's information and to the attendance register mirror.	Essential
4	Allow to inform monthly or in a certain period the amount of hours available to be used as time off.	Essential
5	Automatically unenroll the trainee if he is dismissed.	Desirable
2.4 Definitions and acronyms		
Order Number	Term	Definition
1	Face Registration	Registration of the trainee's face frames.
2	User Registration	Registration of user information.
3	Face Verifier	Identify the trainee by comparing the <i>Webcam</i> capture to the face library.
4	Proof via <i>e-mail</i>	Document via <i>email</i> with the data regarding the time clocking registration.
5	Query System	System for visualization of time clocking registers.

Source: Authors, (2022).

IV.2 DEVELOPING THE SYSTEM LAYOUT

In the development of the system layout was necessary the use cases that according to [21] represent "[...] a set of functions that the system must perform to meet customer requirements". Therefore, the use case diagrams should demonstrate the essential functions of the system. In this diagram model there are the actors, who interact directly with the system functions. The time clocking control use case modeling is presented in Figure 2.

In the diagram, the "trainee" actor has access to "Time clocking Registration" and thus receives a "proof via email", and

can also "Consult the registration report", in other words, he can make the registration, check the registration report and the amount of bank hours. An observation to be made is that the "proof via email" is only sent when the "clock in/out" action is exclusively performed. The "Supervisor" actor has access to the "Registration/Report Control", "Trainees face library" and "Registration Control", and all this when "Query Registration Report", that is, he/she can insert, change, delete and update the user's (trainee's) registration. Thus, we classify the user types into administrator (supervisor), trainees and super-administrator (developers).

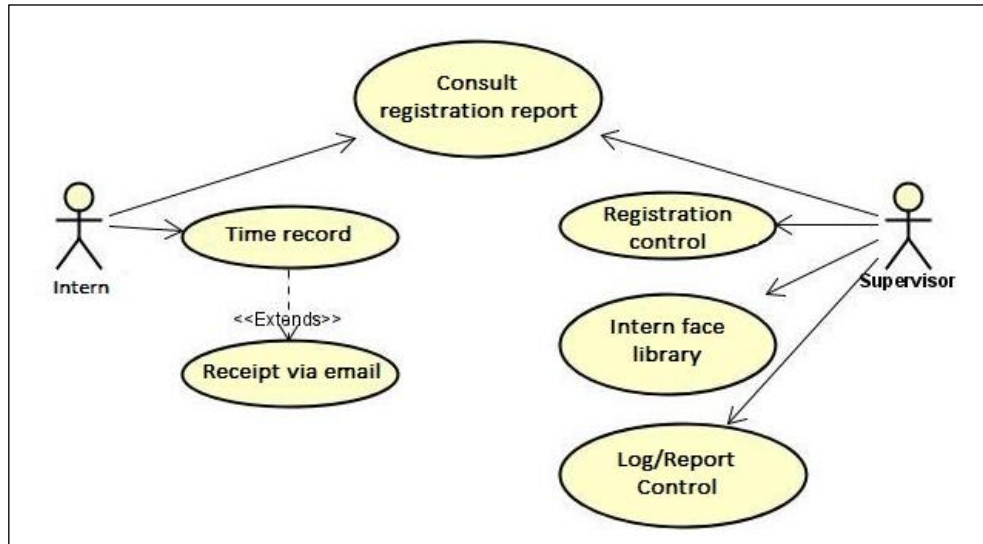


Figure 2: Diagram representing the use of the Time Clock.

Source: Authors, (2022).

In [21] the author explains that the activity diagram is a resource that "allows modeling the system behavior, denoting the logical paths that a process can follow ". In the system, the main activity diagram is the trainee's time clocking record, where the trainee performs facial recognition and has two conditions: if the

face is not registered, it is requested to do so; if the face is registered, then the identification is done, consequently the record of entry/exit of the working day that, finally, sends a voucher via email. This process can be seen in Figure 3 below.

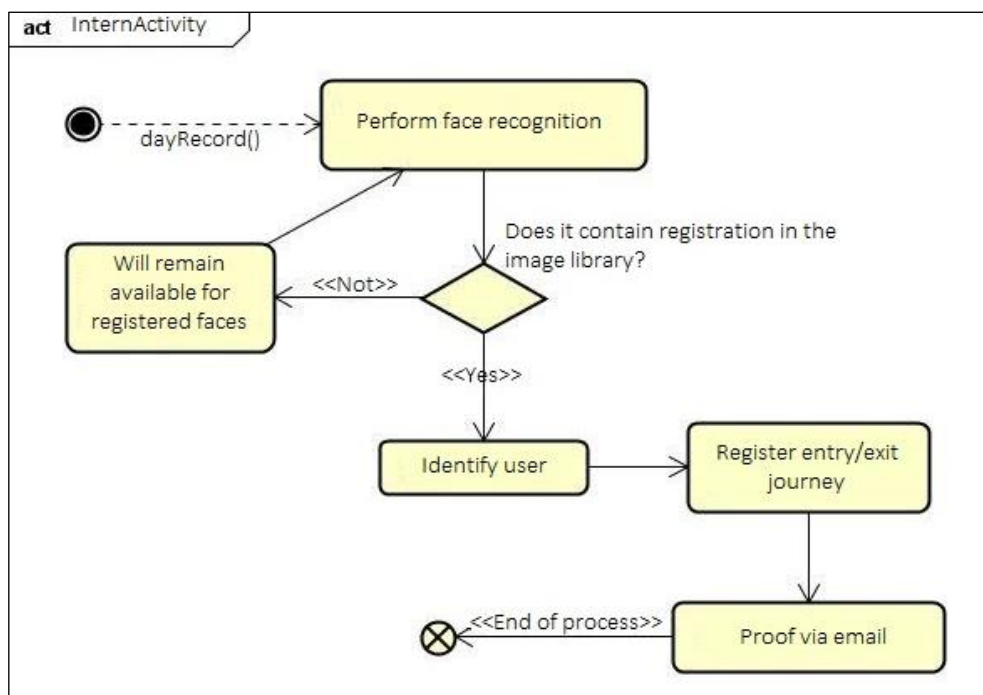


Figure 3: Intern's clocking time register diagram.

Source: Authors, (2022).

Prototyping is a technique used by developers to make an abstract idea, only registered in documents and diagrams, very close to the final product. In addition, prototypes "reduce project uncertainties, as they are an agile way to abandon alternatives that are not well received and, therefore, assist in the identification of a more assertive final solution" [22].

In this prototype we have a database developed in a web interface that stores the information for queries and registration procedures. Figure 4 shows the system's data storage process and is divided into the following entities: "trainee", "timesheet" and "supervisor", where each entity has its attributes which are information to be stored, that is, tables within the database. Thus, the attributes for the user will be fields to be filled in with the requested data.

The trainee's attributes are: name, e-mail, enrollment, shift (morning or afternoon), gender, date of birth and id. An observation about the id: it is an internal identification given by the database, this occurs uniquely for each attribute and is seen only by the developer. To continue, the attributes of the timesheet are: day, month, year, time of registration, overtime, extra minute, and id. The supervisor's attributes are: name, role, email and id.

The database has classifications of relationships, and these have been previously defined. So, in this system there are two relationships: the query relationship which is N-N (many to many) when it comes to the "supervisor" entity, that is, he can query any profile of the "clocking sheet" entity; and the record relationship which is 1-N (one to many), where the "trainee" can record several times in the "clocking sheet".

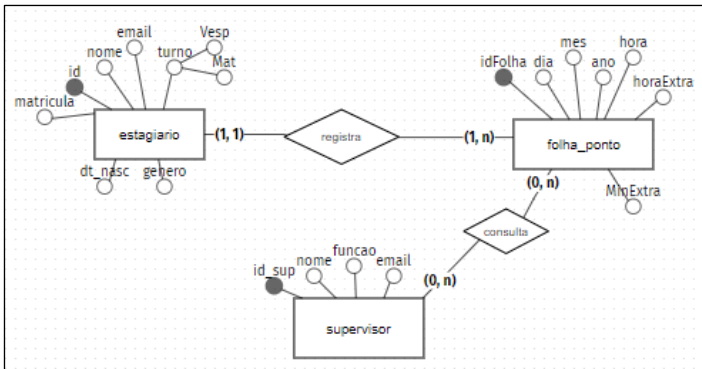


Figure 4: Process of storing the system data.
Source: Authors, (2022).

IV.3 DEVELOPMENT OF THE TIME CLOCK

The language chosen for the development of the system was Python, because using it in the PyCharm IDE there is a variety of packages that are fundamental in facial recognition and that assist in the system performance. This way the following packages were used: OpenCV, numpy, OS, Datetime, email.message, smtplib, tkinter and Mysql. And, for the dynamics of the process, two subsystems were developed, one that performs the function of registering faces in the image bank and the other to identify the trainee through facial recognition and record the time clocking.

IV.3.1 Registration of Trainees in the Database

Initially it was developed as the subsystem that has the objective of performing the registration of trainees through a form created with the help of the Tkinter library, obtaining all the relevant personal and professional information cataloged in the requirements survey highlighted in the topic 4.1. This data was used as parameters for the other processes to identify the faces in

the image bank and the time clocking record. The trainee registration can also be performed by the web system, which is treated in topic 4.3.4.

Tkinter is a Python language library that comes with the standard installation and allows you to develop graphical user interfaces. This means that any computer that has the Python interpreter installed is capable of creating graphical interfaces using Tkinter, with the exception of some Linux distributions, requiring the module to be downloaded separately [23].

The form, shown in Figure 5, has the following fields: ID, Name, Date of Birth, Gender, E-mail, and Shift of the trainee.

Figure 5: Intern registration form.
Source: Authors, (2022).

After filling out the form, the system needs to connect to the database to store the information, and for this the mysql API was used, which, according to [24], allows an application to connect and interact with a database system.

Figure 6 demonstrates connecting to the database and directly accessing the "bdhoras" database by passing the "host", "user" and "password" parameters to connect, which has all the trainee, user, supervisor and time clocking record information tables.

```
def conectandoBD():
    cnx = mysql.connector.connect(
        host='localhost',
        user='DBUSER',
        password='DBPASSWORD',
        database='bdhoras'
    )
    conexao = conectandoBD()
    cursor = conexao.cursor()
```

Figure 6: Database connection function and instance.
Source: Authors, (2022).

Next, the information collected by the form in figure 5 is stored in the database through the function "registroEstagio", shown below in Figure 7.

```
def registroEstagio(idMatricula, Nome, genero, turno, dtnasc, email):
    dataBD = datetime.strptime(dtnasc, '%d/%m/%Y').date()
    cursor.execute(f"USE {DATABASE}")
    comando = f"INSERT INTO estagiario " \
        f"(idMatricula, nome, genero, turno, dt_nasc, email) VALUES " \
        f"({idMatricula}, '{Nome}', '{genero}', '{turno}', '{dataBD}', '{email}')"
    cursor.execute(comando)
    conexao.commit()
    print("Dados inseridos com sucesso")
```

Figure 7: Function for registering an Intern in the database.
Source: Authors, (2022).

The database management system is powered by MySQL Workbench. This holds all the data that the system can provide, such as information about registered trainees and supervisors, as well as time clocking registration data and user registration with a login and password. See Figure 8 below.

Table: folha_ponto	Table: estagiario	Table: usuario	Table: supervisor
Columns: idRegistro int AI PK dia varchar(45) mes varchar(45) ano varchar(45) hora time BH_hora int BH_min int BH_total date idEstagioReg int	Columns: idMatricula int PK nome varchar(45) genero varchar(45) turno varchar(45) dt_nasc date email varchar(45)	Columns: idusuario int AI PK login varchar(45) senha varchar(45) tipo int idEstagiario int idSupervisor int	Columns: id_sup int PK nome varchar(45) funcao varchar(45) email varchar(45)

Figure 8: Registered users' information bank.
Source: Authors, (2022).

IV.3.2 Registering Faces to the Image Bank

In this process the functionality of the subsystem that performs the registration of frames in various positions of the trainees' faces that were captured by the computer's webcam for storage in the pre-defined directory created by the system was addressed.

Initially, to create the image bank storage directory, it was necessary to use the OS package which, according to Lima [25], provides functions to interact with the operating system. OS, comes in Python's standard utility modules. This module provides a portable way to use operating system dependent functionality.

Among the various functionalities, the OS was used mainly to create the function "creatDir" shown in Figure 9, whose execution is to manipulate the system to generate a folder, if nonexistent, in the project's root directory, and inside it, a new folder is created that receives the name of the variable "matricula", which corresponds to the identifier of each trainee registered by the system for storing the person's face frames.

```
def creatDir(matricula, path=''):
    # verifica se tem um diretorio, se não tem ele cria
    if not os.path.exists(f'{path}/{matricula}'):
        os.makedirs(f'{path}/{matricula}')
```

Figure 9: Image bank directory creation function.
Source: Authors, (2022).

In the sequential structure of the source code, there is the creation of the activity of the function "cadastroDir", highlighted in Figure 10. This is responsible for naming the folder in the system matrix as "USER", where, inside it, a new folder is created, identified by the trainee's enrollment variable, to store the user's face frames.

```
def cadastroDir():
    global cadDir
    cadDir = True
    creatDir(matricula, 'USUARIO')
```

Figure 10: Function invoking "creatDir" for folder creation.
Source: Authors, (2022).

Next, the activity that registers the trainee's frames inside the "USER" folder was developed. And, for this, the library used was OpenCV. This was essential in the function of storing the faces in the system's image bank. The code in Figure 11 highlights the function called "registerImage" which is responsible for mapping the face, being defined as variable "img". And consequently, a folder identified by the trainee's registration number is generated with 100 frames.

```
def cadastroImagem(img):
    # salvando as fotos na pasta do usuário e nomeando elas
    global matricula
    qtd = os.listdir(f'USUARIO/{matricula}')
    cv2.imwrite(f'USUARIO/{matricula}/{str(len(qtd))}.jpg', img)
```

Figure 11: Function for registering faces in the image bank.
Source: Authors, (2022).

It should be noted that this amount of frames does not reach the capacity of 3 megabytes, as can be seen in Figure 12. Therefore, a large number of registered users can be added. And yet, this amount of 100 frames is considered the minimum effective for facial recognition. However, this value can be changed to more, thus being efficient in the identification.

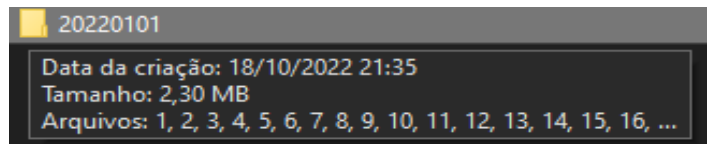


Figure 12: Size of a user's frame folder.
Source: Authors, (2022).

Next, after running the system, the code enters a loop and performs the decision command, in Figure 13. Here the callback execution of the "cadastroDir" function, previously seen in Figure 10, takes place.

After creating the directory, according to the source code in Figure 13, the system accesses the webcam and opens a window where you can keep track of all the images captured up to 100 times in jpg format and name them from 0 to 100. The system then uses the function "cadastroImagem", which uses the parameter "resize", responsible for cropping the trainee's face for storage in the image bank.

```
if cadDir:
    cv2.putText(frame, str(cadRostoCont))
    cadRostoCont += 1 # Incrementando a id
    cadastroImagem(resize) # Salvando os rostos
```

Figure 13: Decision Command for Registering Faces.
Source: Authors, (2022).

IV.3.3 Trainee Authenticator with Facial Recognition

In this topic, the functionality of the subsystem that performs face recognition through real-time capture of the webcam or video device configured by querying the image database of the registered faces detailed in topic IV.3.2 was addressed.

The function "verificador", shown in Figure 14, performs the activity of capturing the face through the webcam and queries the image bank as a scan, through arrays and numeric arrays using the numpy library, if there is any image like it, performing facial recognition. Finally, it searches for the identification number of the folder and stores it in the variable "idents" for comparison purposes by the system.

The numpy library was created in 2005 by Travis Oliphant, the NumPy project was based on the Numeric and Numarray projects with the goal of gathering the community around a single framework for processing arrays. Therefore, the NumPy package, named so because of the abbreviation Numerical Python, is an open-source library designed to perform operations on multidimensional arrays, friendly referred to as ndarray in this library [26].

```
def verificador():
    global recognizer, verifica, pessoas
    pessoas = os.listdir('USUARIO')
    idents = []
    rostos = []
    for i, p in enumerate(pessoas):
        i += 1
        for f in os.listdir(f'USUARIO/{p}'):
            img = cv2.imread(f'USUARIO/{p}/{f}', 0)
            rostos.append(img)
            idents.append(i)
    recognizer.train(rostos, np.array(idents))
```

Figure 14: Face recognition function from the image bank.
Source: Authors, (2022).

Another important function, regarding the registration of time clocking in the database was modeling the function "registrandoHora" using the datetime library that stores the values of the exact moment of day, month, year, and time; and the system performs the calculation of the amount of extra hour and minute, being identified by the user's license plate variable. This process is done by Figure 15.

```
1 def registrandoHora(matriculaBD):
2     tempo = dt.datetime.now()
3     diaBD = int(tempo.day)
4     anoBD = int(tempo.year)
5     mesBD = int(tempo.month)
6     horaBD = tempo.time()
7     comando = f'INSERT INTO banco \
8         f'(dia, mes, ano, hora, idEstagioReg, BH_h
9         opario, BH_hora, BH_minuto) VALUES \
10        f' ({diaBD}, {mesBD}, {anoBD}, "{horaBD}",
11        {matriculaBD}, "{horaFormula}", {qtdH}, {minuto_total})'
12     cursor.execute(comando)
13     conexao.commit()
```

Figure 15: Function for time clocking recording.
Source: Authors, (2022).

Another library used was datetime which for Santos [27] is an object type in Python to deal with dates and times. Whenever you have a variable with days, months, years, hours, you have the chance to transform it into a datetime object and have access to a series of methods to work with it and transform it.

After storing the clocking record, the system sends a voucher via email to the trainee identified by facial recognition.

The function responsible for this activity is the "Sendcomprovante", shown in Figure 16. The text that will be contained in the email is structured by the "corpo_email" variable.

```
def SendComprovante(nomeBD, Email):
    corpo_email = f"""
    <p>{saudacao}, {nomeBD}</p>
    <p>Segue seu comprovante de registro no sistema</p>
    <p>Dia: {diaBD}/{mesBD}/{anoBD}</p>
    <p>Hora: {horaBD}</p>
    """
```

Figure 16: Function to send voucher via email.
Source: Authors, (2022).

The text in Figure 16, the body of the email is sent to the recipient using the EmailMessage library which according to [28], provides the core functionality to set and query header fields, to access message bodies and to create or modify structured messages. Alongside the previous library is smtplib which [29] defines as used for sending email, dictates how the email will be formatted, encrypted and transmitted through online servers in addition to other details that the computer uses.

With the EmailMessage and smtplib library you can define which sender and recipient the system will send the voucher to. Figure 17 shows the process of defining the email subject, the sender, which will always be the address "sistema.sejusc@gmail.com", and the recipient, which will be the registered email address of the identified trainee.

```
msg = email.message.Message()
msg['Subject'] = f"Comprovante Registro ({tempo})"
msg['From'] = 'sistema.sejusc@gmail.com'
msg['To'] = Email
password = 'bkqxxzbbdkqaxpth'
msg.add_header('Content-Type', 'text/html')
msg.set_payload(corpo_email)
s = smtplib.SMTP('smtp.gmail.com: 587')
s.starttls()
s.login(msg['From'], password)
s.sendmail(msg['From'], [msg['To']], msg.as_string().encode('utf-8'))
```

Figure 17: Process of sending the e-mail.
Source: Authors, (2022).

In short, after all the creations of the functions discussed in this topic, the facial recognition subsystem, when in operation, performs the real-time capture of the webcam and checks the image bank to see if there are identical faces stored. If the system detects the trainee's registered frames, the trainee's information is searched in the database, the time clocking is registered through the function "registrandoHora" (Figure 15) and the proof of registration is sent through the function "sendComprovante" (Figure 16). The described process is structured and performed by the decision command depicted below in Figure 18.

```
if verifica:
    dados = userBanco()
    idf, conf = recognizer.predict(resize)
    idEstagio: int = pessoas[idf - 1]
    for dados in dados:
        if int(idEstagio) == int(dados[0]):
            nomeBD = dados[1]
            emailBD = dados[5]
            matriculaBD: int = dados[0]
            registrandoHora(matriculaBD)
            Email = f'{emailBD}'
            SendComprovante(nomeBD, Email)
```

Figure 18: Trainee identification for time clocking recording.
Source: Authors, (2022).

IV.3.4 Web development for querying time clocking registration

The web development was not the project's goal, but its rationale was commented on, because it serves as a consultation of the user's (trainee) time clocking record, being this a "bonus" function adhered to the system. This was based on HTML 5, CSS, PHP, JAVASCRIPT, Xampp.

The result of this development step can be seen in the following sequence of pictures, where user 2 was used as an example.

The layout of the login screen for supervisor and trainee access can be seen in Figure 19 below. It was designed to be objective and intuitive, so it has only two fields to be filled in: user and password; and a login button.

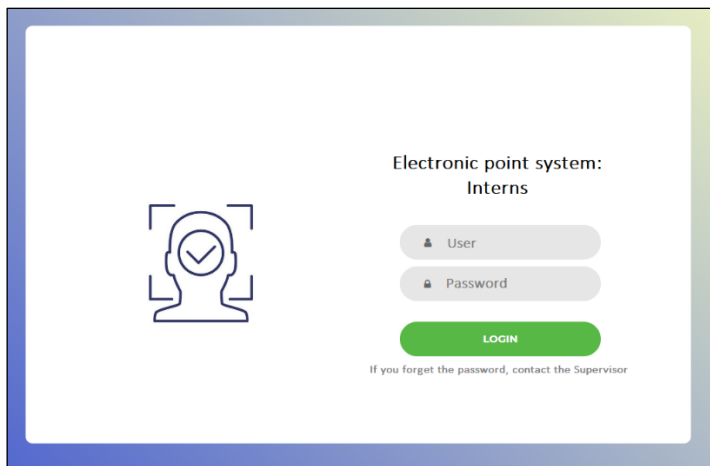


Figure 19: Login Screen. Source: Authors, (2022).

After logging in, the home screen is shown, in Figure 20, and is composed of three buttons (dashboard) (located in the central part of the screen): "Trainees", "clocking time registered" and "Users". In addition, there is a yellow column with other buttons: "home", "users", "trainee", "timesheet", "about" and "logout".

It should be noted that the screens shown below are seen when the supervisor logs into his account, so he has access to all possible and necessary information.

Furthermore, in the bottom right corner of the button there is a variable that refers to the amount of existing records (registered) in the database for each field, i.e there are 2 users, there are 11 registered clocking times in total and there are 3 trainees in total. This is updated automatically.



Figure 20: Home Screen. Source: Authors, (2022).

Accessing the "users" button (either through the yellow column or the dashboard) shows a list of the users that are registered in the system, i.e., trainee and supervisor. In addition, information such as registration, user type and user level are also shown. See Figure 1 below.



Figure 21: List of users. Source: Authors, (2022).

Following the yellow column, clicking on the "trainee" button shows a list with information such as registration, name, gender, shift and e-mail regarding the registered trainee. You can also change the registration data, by clicking on the "pencil" icon, and delete a trainee, by clicking on the "trash can" icon. See Figure 22 below.

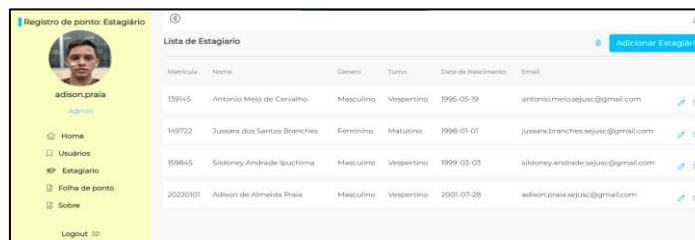


Figure 22: List of registered trainees. Source: Authors, (2022).

The next screen, Figure 23, is visualized by clicking on the button "Time Sheet", on this page the supervisor can access not only the report of the record of all the trainees by clicking on the icon "eye" located in the View column, but also the information. However, this is the only option that appears for the trainee, i.e., this is where he can check his time clocking report individually.



Figure 23: Trainee's list for time clocking consult. Source: Authors, (2022).

In the last screen, Figure 24, after clicking on the view icon, all the clocking records done by the trainee are shown. It has the following data: registration, name, day, month, year, hours, overtime, extra minutes and total in time format.

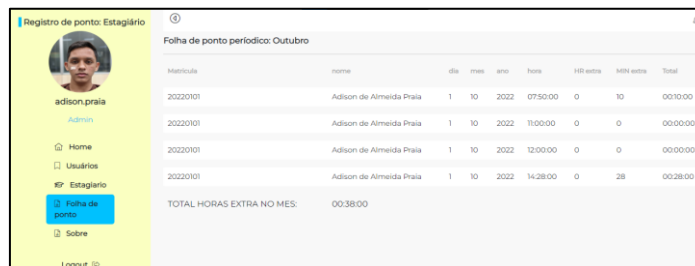


Figure 24: Trainee's time clocking register screen. Source: Authors, (2022).

IV.4 TESTING THE SYSTEM USING THE USERS' FACE DATABASE

In this item, the process of the system's operation with the users' face database was presented, as well as the tests and errors that were essential to verify the product's limits and, finally, to implement it in the ITM.

IV.4.1 System operation process

The system, at first, trains the trainee's face and generates not only the folder with the user's name, but also 100 frames of his face. These have to be transformed to an easily identifiable shade, so they can't be colored, so all were converted to gray as can be seen on Figure 25. In this example, there is user 2.



Figure 25: Trainee's clocking register screen.
Source: Authors, (2022).

The step-by-step process of registering a user (trainee) to the system was divided into 6 steps that can be seen below.

STEP 01 - New trainee registration form: in this window it is necessary to fill in the fields with the registration number, full name, date of birth, gender, e-mail and shift. Then, just click on the register customer button, and the new trainee is added to the database.

Figure 26: Registering the trainee profile.
Source: Authors, (2022).

STEP 02 - The data entered on the form are registered in the MySQL Workbench database in the table "estagiario". In which the "idMatricula" is mandatory, as it is a unique attribute, non-repetitive, used to identify each trainee.

idMatricula	nome	genero	turno	dt_nasc	email
139145	Antonio Melo de Carvalho	Masculino	Vespertino	1995-05-19	antonio.melo.sejusc@gmail.com
149722	Jussara dos Santos Branches	Feminino	Matutino	1998-01-01	jussara.branches.sejusc@gmail.com
159845	Sildoney Andrade Ipuhima	Masculino	Vespertino	1999-03-03	sildoney.andrade.sejusc@gmail.com
20220101	Adison de Almeida Praia	Masculino	Vespertino	2001-07-28	adison.praia.sejusc@gmail.com

Figure 27: Trainee data.
Source: Authors, (2022).

STEP 03 - Registering faces for storage in the image library: in this window a blue frame is shown that is limited to the face of user 2. Besides, there are two options: press the 'C' key on the keyboard to register 100 frames of the face and the "e" key that closes the system.

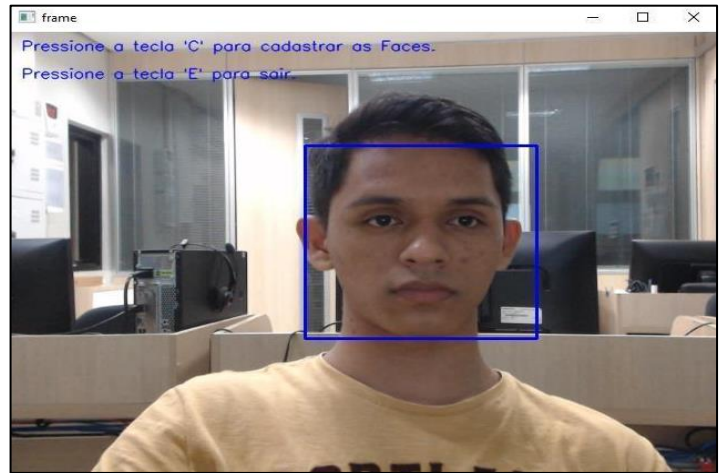


Figure 28: Face registration screen.
Source: Authors, (2022).

STEP 04 - Facial Recognition through Webcam: Checks to see if it contains an identical frame in the image library and fetches the information from the database.

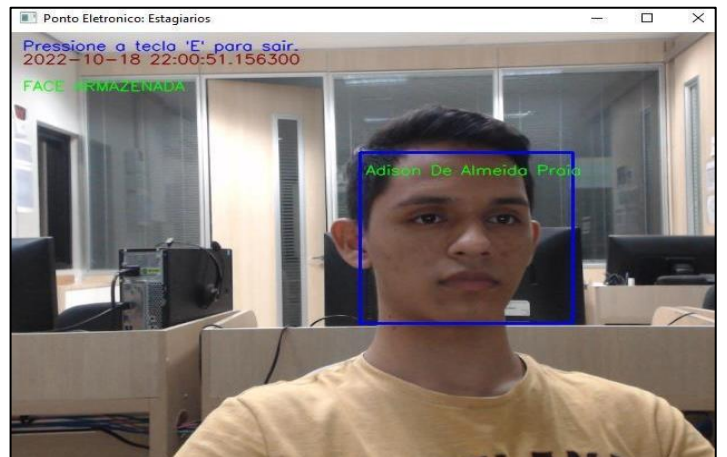


Figure 29: Face authenticator screen.
Source: Authors, (2022).

STEP 05 - Time clocking recording in the database. After performing facial recognition, the system records the time in the "timesheet_points" table. Each record is identified by the "idEstagioReg" column, which corresponds to the primary key of the "estagiario" table, making it possible to differentiate which record belongs to each trainee. The date was also segmented by day, month and year, giving the option to separate the data by a certain period of time.

	idRegistro	dia	mes	ano	hora	data	idEstagioReg
▶	21	18	10	2022	21:58:07	2022-10-18 21:58:07	20220101
	22	18	10	2022	22:06:41	2022-10-18 22:06:40	18102022
	23	18	10	2022	22:07:44	2022-10-18 22:07:43	20220101
	24	18	10	2022	22:17:54	2022-10-18 22:17:54	20220101
	25	18	10	2022	22:18:02	2022-10-18 22:18:01	20220101
	26	18	10	2022	22:18:08	2022-10-18 22:18:07	20220101
✖	NULL	NULL	NULL	NULL	NULL	NULL	NULL

Figure 30: Table "time_sheet".
Source: Authors, (2022).

STEP 06 - Finally, after the registration of the time clocking record in the database, the system sends a clocking record voucher to the trainee's registered email address. This voucher is sent automatically by the system, and is always sent to the address: sistema.sejusc@gmail.com.

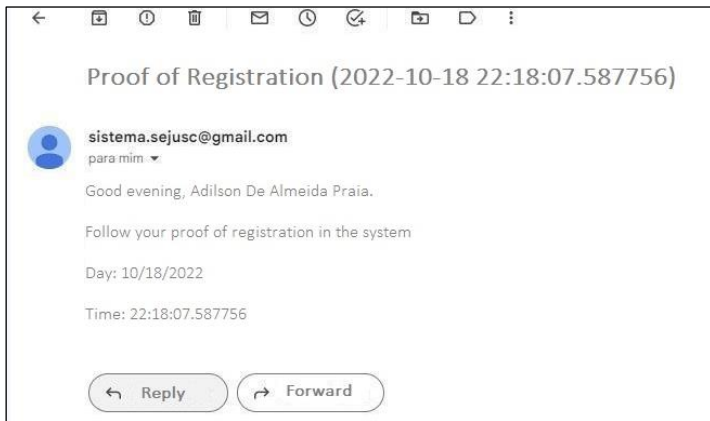


Figure 31: Proof of Registration via E-mail.
Source: Authors, (2022).

IV.4.1 Tests and Errors

Starting the tests, the registration of "user 1", "user 2" and "user 3" were done with a low quality webcam (VGA) and in a place with poor lighting. Because of this, an error was observed when performing facial recognition for each of the users. User 1 had the correct name, while "user 2" had the name of "user 1". See the following comparison of the error between Figure 32 and Figure 33.

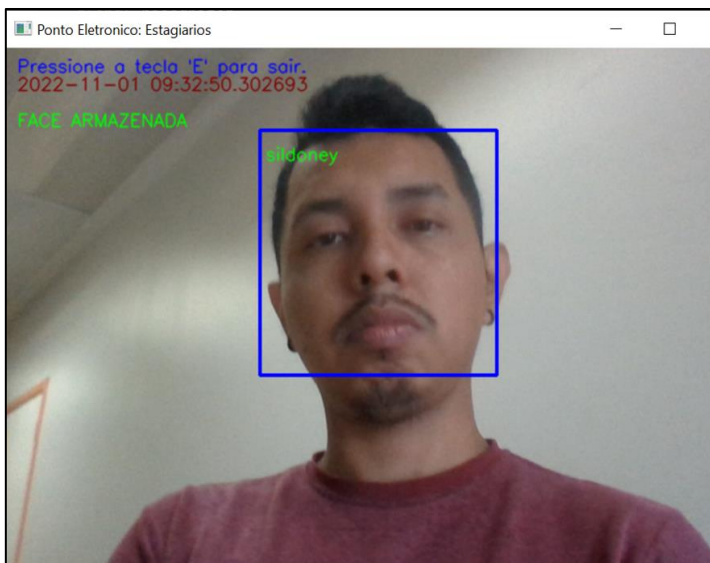


Figure 32: User 1 with correct name.
Source: Authors, (2022).

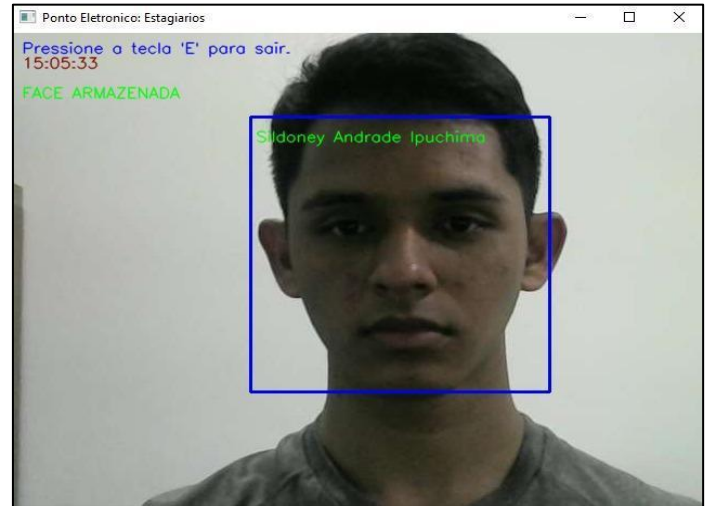


Figure 33: User 2 with user name 1.
Source: Authors, (2022).

The error occurred due to the mentioned conditions, and when registering, the frames were generated with low quality, causing the user's face traces to look similar. Take, for example, the "user 1" frames folder.

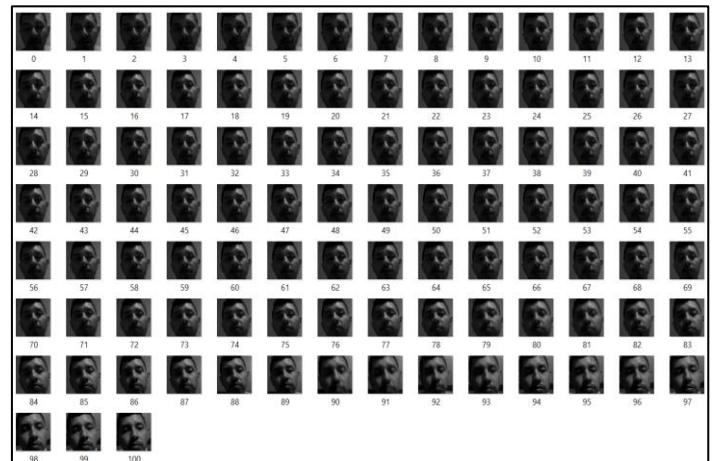


Figure 34: Folder with frames from user 1 with low quality.
Source: Authors, (2022).

IV.5 IMPLEMENTATION OF THE SYSTEM IN THE ITM OF SEJUSC

Joining Biometrics, Artificial Intelligence, Data Structuring, Programming Language, and Database it was possible to create the project, that is, the system was developed based on available technologies and easy access to information.

With the integration of the electronic time clock to ITM, it was possible to automate the frequency registration system that was

previously done manually, and to optimize the overtime accounting process.

The procedure was started by registering the trainees, adding their personal data. It was important to note that the institutional e-mail should be used, because the receipt is sent through there. And later, they did the face registration. So, every day, from Monday to Friday, when they arrived and left, each on their respective shift, they were able to register their attendance.

On the days when overtime was needed, the trainees logged 1 hour after their normal time off, this was the maximum amount of overtime agreed upon between the supervisor and the trainees. And their record report is seen on the web system, as well as being received by email.

Now, with the automated process, the supervisor has access to each trainee's attendance record report, where he can check the amount of overtime, where he can fairly offer the amount of days off.

V. CONCLUSIONS

The project was based on applied research, thus, it aimed to address the problems observed in the sector of Information Technology Management (ITM) located within the State Department of Justice, Human Rights and Citizenship (SEJUSC). One deficiency of the sector was related to the frequency control, while the other was the high demand of services having the need to work overtime and within this context were the interns.

As a result, along with the solution found by the ITM supervisor to offer time off to those trainees willing to work overtime, in a way to optimize and automate the working day, an electronic time off system was developed for trainees based on facial biometrics, Python language and database.

In addition, the methodology adopted was research of theoretical references, interviews, and data collection from the trainees, and also the materials used as low-cost technological tools were fundamental and essential to achieve the general objective. This was delimited in five specific objectives that were satisfactorily met.

The demand of the sector was analyzed, as well as the dynamics of the trainees' working hours, this being the first step taken within the methodology. In the sequence, the project's layout was created, thus following to the stage where the system and the database were developed. In view of this, arriving at the penultimate step, the system was tested through the trainees' library of faces. Finally, the implementation was done in the ITM sector of SEJUSC.

The development of the project was based on available technologies and the ease of access to information, and the following hypothesis was raised: by joining facial biometrics to the idea of an electronic time clock that emits the amount of days off would make the sector's attendance system optimized and safe?

In summary, it was possible to develop an electronic system that met the needs cited. This system, which is low cost, was implemented in the ITM and served to assist the supervisor who, now, with the report of the overtime bank, can offer optimally the correct amount of days off to the trainee. And, thus, making the time record automated.

In future research, it is recommended to improve the use of facial biometrics, where the recognition is limited to the face without the use of accessories, and also to look for better technologies regarding low light. In addition, it is suggested to switch or use voice biometrics together, so that the system can be activated without the need for contact and without using peripherals (mouse and keyboard), and perhaps making it faster.

The project developed was a great opportunity to complement and improve the academic training. In addition, it allowed students to put into practice the contents studied as a basis in the Computer Science course, such as Biometrics, Artificial Intelligence, Data Structures, Programming Languages and Databases. Applying in practice the concepts, fundamentals, definitions and software studied in the classes, and finally, understanding the importance of the elaboration of a scientific article and for the scientific community.

VI. AUTHOR'S CONTRIBUTION

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Supervision: Alexandra Amaro de Lima.

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RESEARCH ARTICLE

OPEN ACCESS

OFF-GRID MOBILE PHONE CHARGING SYSTEMS FOR RURAL ENERGY NEEDS

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ABSTRACT

For several decades, rural electrification has remained a formidable challenge, particularly in Nigeria. Financial constraints, difficult rural terrain, inefficient policy, and a lack of industrial community development have all contributed to the grid expansion problem in these areas. These areas are energy-deficient, and their energy demands to keep up with cutting-edge communication technology are constantly rising. As a result, rural areas are confronted with the issue of charging. Consequently, many rural residents are forced to rely on diesel/petrol generators or travel long distances and pay a premium to have their mobile phones charged. Thus, this paper proposes an off-grid solar-powered charging system as an alternative, sustainable solution to meet rural mobile phone energy demand. The methodology employed six-tier architectural features, with the economic comparison metric based on net present value and payback period. Furthermore, the proposed model's performance analysis revealed that the charging rate is dependent on the phone battery type and charger type. Furthermore, the off-grid mobile charging system has a higher net present value (\$20,658US) and a shorter payback period of 2.5 years than the alternative investment of a gasoline generator.



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I. INTRODUCTION

Access to energy has long been recognized as a key component in alleviating poverty, improving economic status, and promoting sustainable development [1]. Global energy demand is rapidly increasing with major growth in sub-Saharan Africa [2]. Hence, the demand for electricity exceeded the capacity of the grid, resulting in an energy imbalance. Unfortunately, energy production in terms of generation has declined significantly over the years and most energy users rely on non-renewable energy sources such as biomass/fuelwood, natural gas, and diesel/petrol generators to meet this growing demand. For a plethora of reasons, the use of energy-efficient technology and renewable energy have recently become a focus in rural electrification projects in emerging nations seeking to meet the Sustainable Development Goals (SDGs).

African countries are endowed with a wealth of natural and renewable resources, but they lack access to electricity, clean energy, and energy security [3]. As of 2020, nearly 770 million people in Africa lack access to electricity services, accounting for

55% of the global population, with the majority of them living in rural areas [4]. Table 1 shows that Nigeria currently has limited access to electricity in comparison to other African countries. These countries have seen significant improvements as a result of increased use of renewable energy sources to alleviate rural bottlenecks and accelerate rural electrification.

Table 1: Electricity Access by Country (Cameroun., Nigeria, Ghana, Tunisia, Morocco, and South Africa).

Country	Electricity Access rate in 2020	Renewable energy share target (%)
Cameroun	91%	n.a by 2030
Nigeria	75%	6% by 2030
Ghana	85%	10% by 2030
Tunisia	100%	30% by 2030
Morocco	100%	52% by 2030
South Africa	84.4%	75% by 2030

Source: Authors, (2022).

Furthermore, the proliferation of mobile phones (MPs) and recent advances in communication technology are rapidly increasing electricity demand, contributing to Nigeria's energy deficit. Nigeria currently has over 98 million mobile phone (MP) users. Unfortunately, the expansion of the MPs network without adequate growth in the grid network has denied access to electricity to over 90 million MPs. As a result, users who want to charge their MPs but do not have access to electricity face a charging problem, especially in rural areas where there is a high demand for MPs. MP users were sometimes forced to travel long distances and pay a higher cost to charge their MPs because they were not connected to the grid network. In order to meet their electricity needs, these MPs users rely primarily on the use of gasoline generators. Consequently, CO₂ emissions and other high-polluting emissions have increased, contributing to environmental degradation and global warming. However, the desire for carbon reduction and stable electricity access has led to the development of solar-powered multiple cell phone charging booths.

Several studies [5]–[7] have used photovoltaic (PV) solar to charge MPs. [8], demonstrated a low-cost prototype solar-cell-powered smart phone charger. Forest et al. [9], developed a software based platform for testing solar powered chargers. Jemal et al.[10], created a solar power pack to charge MPs. [6], used an experimental approach to investigate the power and energy consumption of MPs charging. Their findings show that the average energy use per MP charger ranges from 7Wh to 13Wh, and inverter efficiency is directly proportional to the number of MPs. Furthermore, it should be noted that single and multiple phones have nearly 50% and 85% efficiency, respectively, and that the peak power of an MP is approximately 7W. A photovoltaic (PV) system is used to recharge MPs. Schuss et al.[11], presented designed requirements for solar-powered MP chargers and suggested that conventional chargers should be modified to meet user demands. [12], proposed a solar-powered charging station for MPs. Talit [13], powers MPs with a wireless charger. His findings highlight the significance of light intensity in wireless charger charging time. Qutaiba [14], designed a solar-powered phone charging station.

The [15], investigated the factors influencing MPs in Nigeria. Their findings reveal a variety of factors that influence the use of MPs in Nigeria. Sada et al. [16], used Simulink to analyse

the performance of a PV module and a thermoelectric generator for MPs charging. According to their findings, the charging voltage should not exceed 4.5 to 5V, and there is no limit on the amount of current that can be used to charge a battery, MPs, or tablets.

Solar energy harvesting is a key sustainable pathway for enhancing rural electrification projects and meeting some of Africa's SDGs, particularly in Nigeria. In fact, the use of sustainable energy has enormous energy and cost savings potential. Therefore, the objective of the present study is to develop a solar powered multiple mobile phone charger that can:

- Offset grid energy insecurity in rural areas for MPs charging applications.
- Reduce extra costs associated with MPs charging in the absence of grid connection.
- To reduce reliance on fossil-fuel-based generators and reduce CO₂ emissions.

II. MATERIALS AND METHODS

II.1 PHOTOVOLTAIC CELL (PV)

A photovoltaic (PV) cell, also known as a solar cell, directly converts solar energy into electrical energy. PV cells are connected in a series configuration to form module. The PV module is simplified by using a single diode mathematical model. Each N_p solar cell in solar panel is affected model by current, voltage, temperature and solar irradiation. Hence, the total electric power generated by the PV cells is given in Eq.1.

$$P_{pv} = f(A_{pv}, I_{pv}, T_{pv}, V_{oc}, \alpha_{pv}, I_o, H_{pv}, m_{pv}) \quad (1)$$

Where, A_{pv} , is the panel surface area [m^2], I_{sc} is the open circuit current [A], (T_{pv}) denotes solar cell temperature [K], V_{oc} open circuit voltage [V], α_{pv} is the tilt angle of PV module towards light source [$^\circ$], I_o is the specific cell current [A], H_{pv} denotes the solar irradiation [w/m^2], and m_{sc} is the material of the PV module.

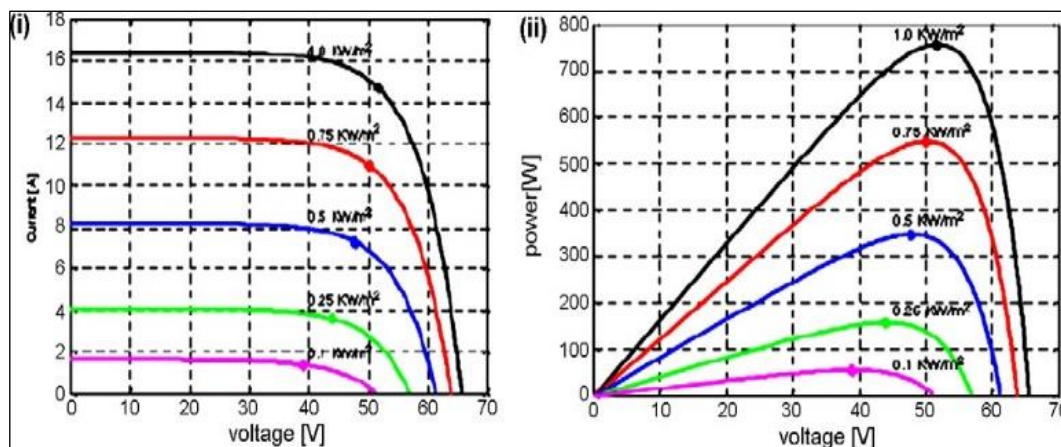


Figure 2: (i) Photovoltaic cells I-V curve and (ii) Photovoltaic cells P-V curve. Source: [17].

The power-voltage curve characteristic for a photovoltaic array operating at a typical irradiance and temperature of $1000 w/m^2$ and $25^\circ C$ respectively is shown in Fig. 2. The solar

irradiation H_{pv} varies with time. Hence, the PV output is dependent on the variation in solar irradiation such that H_{pv} are evaluated as proposed by [18] as:

$$H_{pv} = R_b \left[H_b + H_d \left(1 + \frac{1}{R_a} \right) \right] \quad (2)$$

Where R_a is the tilt factor for the beam, H_b and H_d are the global and diffuse irradiation $[Kwh/m^2]$. The theoretical relationship between the solar panel efficiency and the solar cells temperature is given by [19] as:

$$\eta_{pv} = \eta_o \left[1 - \gamma_o (T_{pv} - T_{air}) \right] \quad (3)$$

Where,

$$\eta_o = \eta_m \eta_{pc} \quad (4)$$

Here, η_m is the solar module efficiency, η_{pc} is the power conditioning efficiency, T_c solar cell temperature, T_a ambient temperature, and γ_o is the array efficiency temperature coefficient.

II.2 BUCK CONVERTER (BC)

A buck converter serves as a dc-dc converter for the charge controller. Its purpose is to maximize power output by balancing the impedance of the solar panel and the battery. In this study, the DC converter uses tracking algorithms to track the voltage and current from the solar panels and adjusts the duty cycle of the filtering signal accordingly to achieve maximum power transfer.

II.3 SOLAR CHARGE CONTROLLER (SCC)

A solar charge controller (SCC) is a power regulator that uses maximum power point tracking (MPPT) algorithm to maximize the amount of power going into battery from PV module to prevent overcharging. It is only necessary for battery-powered systems. SCC's primary function is to monitor battery charging and discharging. The SCC extract the maximum available power from the PV module at an operating voltage (V_{op}). The MPP of SCC varies with changes in temperature, solar variation H_{pv} , and ambient conditions.

For maximum power transfer the operation voltage must be equal to the voltage V^{mpp} otherwise, the obtained output power from the PV array/module $[P_{pv}(w)]$ will be less than the power that can be gained in the MPP as expressed as:

$$P_{pv} = \begin{cases} P_{pv} = P^{mpp}, V_{op} = V^{mpp} \\ P_{pv} < P^{mpp}, V_{op} > V^{mpp} \end{cases} \quad (5)$$

Due to abrupt changes in ambient temperature, V_{op} modification is sometimes required. A microcontroller unit, various sensors, and a DC-DC or buck converter are typical components of a solar PV energy harvester.

II.4 BATTERY SYSTEM (BS)

A battery is a backup energy storage device that converts chemical energy to electrical energy. The battery voltage cell in lithium-ion (Li-ion) batteries is a function of the cell's chemical energy reaction. The cathode, anode, and separator are the three main components of a Li-ion battery, as shown in Fig.3. Copper and aluminum collectors are used as anode and cathode in typical Li-ion cells, respectively. [20].

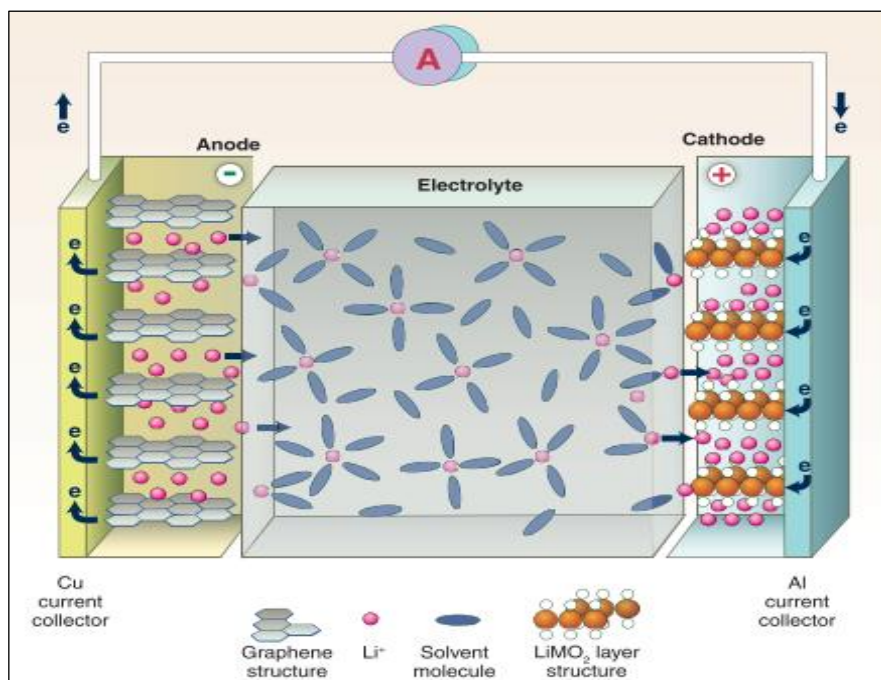


Figure 3: Schematic of Li-ion battery during discharging.

Source: [21].

Due to their longer lifespan, higher power density, and durability, lithium-ion batteries are used in a variety of applications, including electric and hybrid vehicles, smartphones, tablets, computers, wearable technology, and smart and high-tech devices. In this study, two 18650 LiPo batteries with a capacity of 26000mAh and a voltage level of 3,7V are used due to their durability, compactness, low cost, and storage capacity. The charging current I_q varies and depends on the state of charge of a mobile battery (SOC). The charging current is given by [22] as:

$$I_{qc} = \begin{cases} I_{\max}, I_{qc} \leq 80\% SOC \\ I_{\min}, I_{qc} \geq 80\% SOC \end{cases} \quad (6)$$

Hence, the state of charge (SOC) can be expressed as a function of system efficiency, solar module area and solar irradiation as:

$$SOC[\%] = \frac{P_{pv} \times \eta_{se} \times t_{mpc}}{E_{bat}} \quad (7)$$

Where,

$$\eta_{se} = \eta_{pv} \times \eta_{mpp} \times \eta_{bat} \quad (8)$$

E_{bat} denotes the charging energy of the battery [W], t_{mpc} is the amount of time mobile phones are charged [h]. Case 1 illustrates the efficiency and time required for a mobile phone with given specifications.

Case 1:

$$E_{bat} = 8.5W, P_{pv} = 0.3W, t_{mpc} = 4h, \eta_{se} = 80\%$$

$$SOC = P_{pv} \times \eta_{se} \times t_{mpc} / E_{bat} \approx 11\%$$

$$t_{mpc} = P_{pv} \times \eta_{se} / E_{bat} \approx 3\%/h$$

II.5 USB CONNECTOR (USB)

USB, or universal serial bus, is a notable standard interface for connecting a variety of devices to SOC, including mobile phones. Type A and Type B are the most commonly used with phones from the second and third generations. However, the proliferation of smartphones and the need for smart charging has resulted in the invention of mini-USB, micro-USB, and Type C as smart replacements for traditional USB types. USB, or universal serial bus, is a notable standard interface for connecting a variety of devices to SOC, including mobile phones.

Type A, B are the most commonly used with phones from the second and third generations. However, the proliferation of smartphones and the need for smart charging has resulted in the invention of mini-USB, micro-USB, and Type C as smart replacements for traditional USB types. USB, or universal serial bus, is a notable standard interface for connecting a variety of devices to SOC, including mobile phones. Type A and Type B are the most commonly used with phones from the second and third generations. However, the proliferation of smartphones and the need for smart charging has resulted in the invention of mini-USB, micro-USB, and Type C as smart replacements for traditional USB types.

USB 2.0 supports a charging downstream port with a voltage level ranging from 4.5V to 5.5 V with a tolerance of $\pm 5\%$ and a current level up to 1500mA. Figure 4 shows the user specification for USB types in terms of maximum current, power, and voltage. The smartphones use the configurations of data wires D^+ and D^- identify the current chargers.

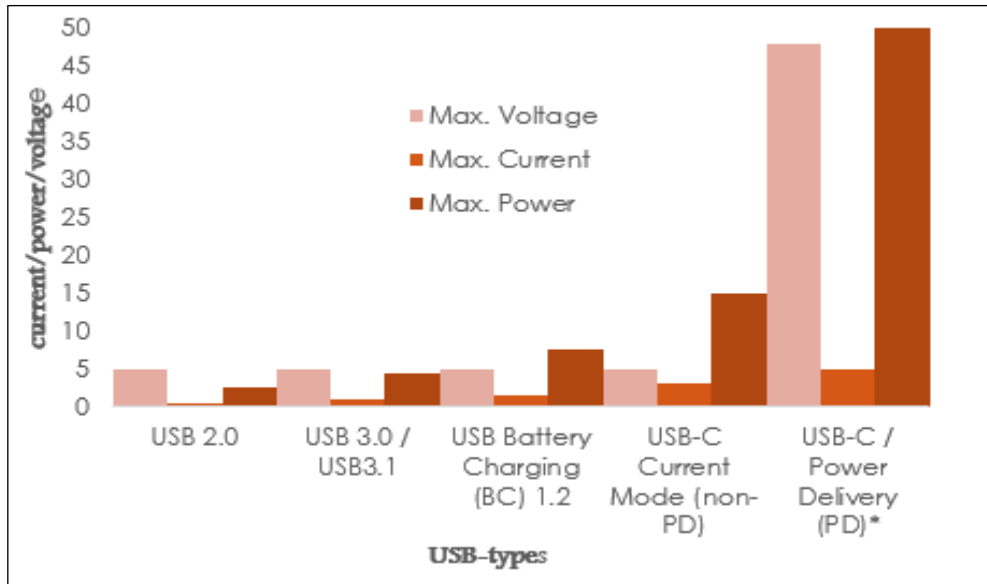


Figure 4: USB Characteristics.

Source: Authors, (2022).

II.6 SYSTEM ARCHITECTURE

Figure.5 is the conceptual framework of the proposed off-grid charging systems. The systems feature six-tiers. Tier-1 consists of a solar PV system, which is an energy harvester that

converts solar energy to electricity. The study uses a 50W, 17.5V monocrystalline solar panels.. Tier-2 is in charge of power conversion and ensuring maximum power output. The charge controller unit is in Tier 3. This is a power regulator that optimizes the amount of power that the PV module sends to the battery in

order to avoid overcharging. Tier-4 is the backup energy storage device. It is powered by a LiPo battery with a capacity of 2600mA and a voltage of 3.7V Tier-5 is the universal serial bus that is used to charge MPs to the SOC. Tier-6 is connected to the MPs devices via a USB cable to improve their charging status.

III. RESULTS AND DISCUSSIONS

III.1 ECONOMIC ANALYSIS

The case study is based on a college of Engineering located in rural area of Ifo local government, ogun state Nigeria. The installed capacity is 50W, which is further extended to 650W to

accomodate future energy needs of the University residents. The system specification is shown in Table 2. The system life span of the gasoline generator and off-grid solar charging systems as well as operating hours is evaluated over 25 years. The investment cost of PV mobile charging systems in Nigeria is about \$1332US/W_p, operating for 6hrs/day or 308days/per year with maintenance cost of 0.05% per year of investment cost span over lifetime of 25 years. The investment cost of 650W gasoline generator is \$200US/W, operating and maintenance cost is 1% per year of investment cost, operating for 25 years lifespan. The gasoline generator runs for 5hrs per day for duration of 322days/years.

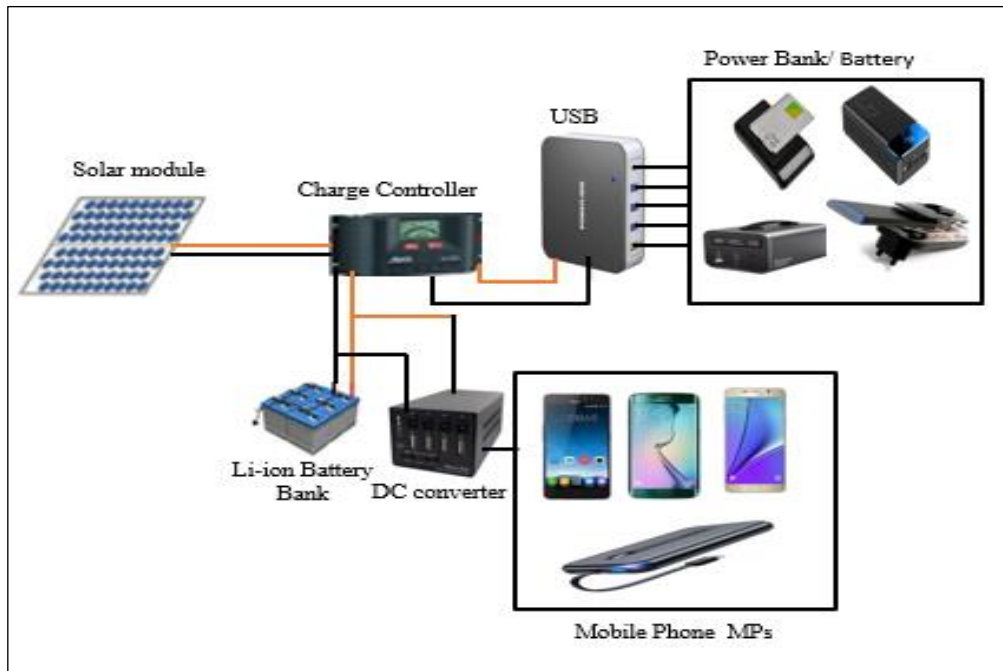


Figure 5: schematic of off-grid solar based charging systems. Source: Authors, (2022).

Table 2: System specification of 650W PV charging systems and Gasoline based generator.

System Discription	System Specification	
Module name	c-Si modules	Gasoline engine (α -generator)
Module size/engine capacity	13(50W/module)	1 unit
Operating hour/days per years	6hrs/days 308days per year	5hrs/day 322days per year
System capacity	650W	650W
Investment cost(IC)	\$1332US	\$200US
O&M cost	0.05%/year of IC	1%/year of IC
Cost of solar/fuel per kWh	0.002kWh	0.24kWh

Source: Authors, (2022).

The cost-benefit comparison analysis of the proposed solar(PV) charging systems and gasoline generator is presented in Table 3.

Table 3: Cost-benefit Assessment for 25 years of 650W PV Charging Systems using c-Si PV modules at electricity cost of 0.12kWh.

Cost-benefit Assessment	c-Si module	α -generato
Annual benefit:		
Electricity save	\$55,440US	\$12,075US
Cummulative benefit	\$55,440US	\$12,075US
Costs:		
Investment cost	\$1332US	\$200US
O&M cost	\$16.65US	\$50US
Fuel cost	[-]	\$384.0US
Cummulative costs	\$1348.65US	\$634US

Source: Authors, (2022).

In economic assessment, there are several economic metrics adopted to ascertain economic viability of any project such metrics includes net present value (NPV), life cycle cost (LCC), benefit-cost ratio (BCR), payack period (PBP) among others. However, the NPV and PBP are important economic metrics used by investor or decision maker in ranking profitable investment projects. Such that the NPV is computed as given by [23] as:

$$\sum_{n=1}^M \beta_n (1+r)^{-j} - \sum_{n=1}^M \gamma_n (1+r)^{-j} \quad (9)$$

Where, β_n is the cumulative benefit at the end of n-years, γ_n denotes the comined cost at the end of n-years, r refers to discount rate, M refers to the number of years in project's lifetime and j denotes each year of the project's lifespan.

Similarly, for most energy-efficiency project, the PBP is the time taken by the new project to recover its cost. Hence, the PBP is given as:

$$PBP = \frac{C_\delta}{S_\delta} \tag{10}$$

Where, C_δ is the cost of efficient system (c-Si PV module) and S_δ denotes the cost of annual energy saving by the efficient system.

These economic metrics is evaluated for the PV moile charging systems and a gasolin generating system and presented in Table 4

Table 4: Economic Assessment comparison between c-Si module and α -generator of 650W capacity systems.

Economic metrics \$US	c-Si modules	α -generator
NPV	20,658	8,570
PBP	2.5	8.75

Source: Authors, (2022).

The economic analysis shown in Table 4 shows that the off-grid PV mobile charging system is a profitable investment with shorten payback period of 2.5 years than the alternative investment of gasoline generator. This implies that the investment cost of c-Si PV mobile phone charging system would be recovered within the 2.5 years and the investor would beining to enjoy the energy cost benefit of the system. In terms of Co2 emmission mitigation, the c-Si PV mobile phone charging system can be an added feature enefit in environmental factors and in the long-term the energy cost

saving potential of the c Si Pv charging system outweight the fuel cost associated with gasoline (α) generator.

III.2 PERFORMANCE ANALYSIS

The proposed system was tested experimentally with various MPs. According to an online survey of students, the three most preferred MPs are the VivoY2, Redmi8, and Samsung Galaxy Note8. Furthermore, the performance index was based on the charging time and power consumption of MPs, as shown in Figures 6-7.

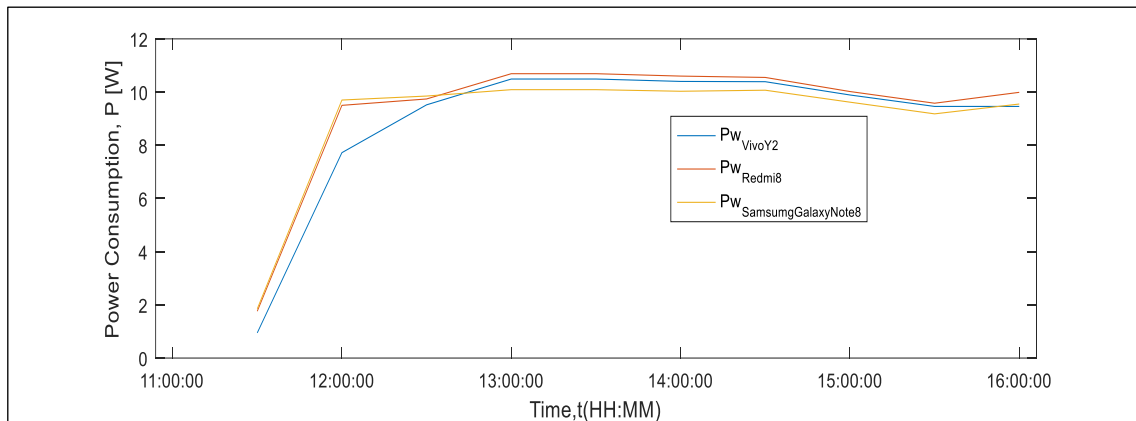


Figure 6: MPs Power Consumption.

Source: Authors, (2022).

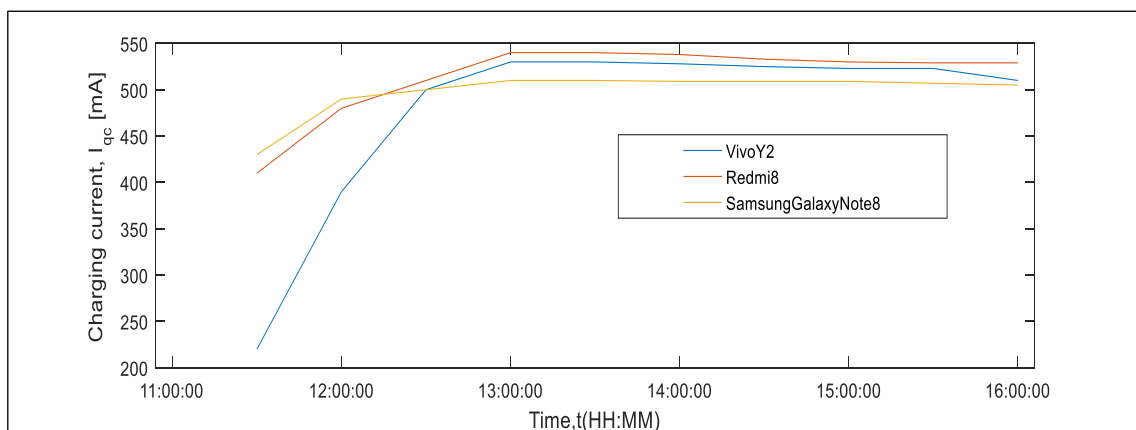


Figure 7: MPs Charging Current.

Source: Authors, (2022).

At maximum efficiency, it takes about 60 minutes to fully charge a Samsung Galaxy Note8 with a battery capacity of 3000mAh from 0% using a charger with a 2 A rating, while a Vivo-Y2 with a battery capacity of 4030mAh takes about 90 minutes to fully charge using a type C charger. Similarly, a redmi8 with a 5000mAh battery capacity takes about 120 minutes to reach full capacity. In terms of performance index, the Samsung Galaxy Note 8 outperforms in terms of charging rate and power consumption. However, their performance is dependent on the type and capacity of the MP's battery, as well as the type of charger used.

IV. CONCLUSIONS

This paper presents an off-grid solar powered charging system as a sustainable solution to rural energy demand needs. The rising energy demand for MP's applications and other lighting devices necessitates a rapid transition to renewable energy and economical, efficient, and co-friendly off-grid energy system. Furthermore, solar energy harvesting is a key sustainable pathway for enhancing rural energy access and mitigate the bottlenecks associated with the expansion of grid network in developing countries especially, in rural terrains. In an attempt to promote clean energy, future adoption of off-grid systems in Nigeria should be viewed as a positive step toward a sustainable path to zero carbon by 2050. The use of off-grid systems is energy-saving strategy for improving energy access and offset grid energy insecurity. Prioritizing government support for off-grid systems will benefit the country's energy supply.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Ayodeji A. Okubanjo.

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Investigation: Alexander A. Okandeji, Martins Osifeko.

Discussion of results: Ayodeji A. Okubanjo.

Writing – Original Draft: Ayodeji A. Okubanjo, Alexander A. Okandeji, Martins Osifeko.

Writing – Review and Editing: Ayodeji A. Okubanjo,

Resources: Ayodeji A. Okubanjo.

Supervision: Ayodeji A. Okubanjo, Alexander A. Okandeji, Martins Osifeko.

Approval of the final text: Ayodeji A. Okubanjo. Alexander A. Okandeji, Martins Osifeko.

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RESEARCH ARTICLE

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USE OF PHOTOVOLTAIC PANELS IN RESIDENCES AS A SOURCE OF PRIMARY ELECTRICITY GENERATION

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ABSTRACT

Population growth at a global level implies an increase in energy consumption by the population. This increase is expected in urban agglomerations composed of residences. The production of energy in the residential area has been discussed when talking about self-sufficiency and clean and sustainable energy. An aggravating factor in the context of forms of energy generation is the great impact of burning fossil fuels that release polluting gases when producing electricity. The present study sought to discuss, based on the literature, the use of photovoltaic panels in the generation of clean energy in homes as an alternative to conventional means. Therefore, the methodology used was based on the search for scientific studies in databases about the proposed theme. A bibliographic survey was carried out in order to obtain studies that would support the research. Studies in the databases Periódicos CAPES, Scholar Google and Scopus were found and selected based on certain criteria. Therefore, it was found that the use of photovoltaic panels in the generation of energy for homes is promising in reducing other energy sources. Several studies show the viability of this type of energy in homes in Brazil, which has a large availability of daily sunlight for its operation. However, the technology in question still has a high implementation cost, which may decrease with government incentives and a decrease in the values of its components. In addition, the use of solar energy compared to conventional means of energy generation has a compensatory value with its long-term use.



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I. INTRODUCTION

With population growth and the increase in the consumption power of emerging countries, the demand for energy is growing. The most recent increases have been mainly in low- and middle-income countries. This growth implies sharp rates of increase in energy consumption, being observed mainly in developing countries, such as in Latin America, where growth was greater than 100% in the last three decades [1].

The high growth rates of the global population living in urban areas intensify the use of energy sources that use the burning of fossil fuels that generate polluting gases such as carbon dioxide (CO²), carbon monoxide (CO), particulate matter (PM) and other gases harmful to the environment and human health.

It is estimated that the contribution of greenhouse gases from electricity generation increases at an average rate of 2.1% per year along with the increase in energy consumption, which grows at a rate of 2.6% globally [2]. Studies prove the influence of pollutant emissions in the atmosphere from anthropogenic actions since the emergence of industry to the present day [3-5].

With the evolution of new technologies in the industrial age, new forms of energy generation were discovered, among them generation by burning fossil fuels, the main ones being: oil (10%), mineral coal (25.3%) and natural gas (20.7%). According to the International Energy Agency (IEA), it is estimated that by 2050 there will be an increase of almost 50% in world energy consumption [6].

Another worrying factor involves the issue of public health, the high concentration of particulate matter and polluting gases from human activities pose risks to human health and are associated with deaths from lung diseases annually [5], [7].

A study carried out with data collected by the World Health Organization (WHO) on particulate matter (PM) - mixture of solid and liquid particles suspended in the air - in 56 of the largest cities in the world showed that at least 96% of the population of the cities studied are exposed to fine particles exceeding the limits established by WHO [8]. Fine particles, especially those with a diameter smaller than 2.5 micrometers, are extremely harmful to health due to their ease of entering the respiratory tract and reaching the lungs.

Solar energy emerges as an extremely abundant source of alternative energy generation. The Brazilian territory has a high potential for capturing solar energy, especially the Northeast region due to its location closer to the Equator. According to the Brazilian Atlas of Solar Energy, the country receives a daily solar incidence of 4,500 to 6,300 Wh/m² throughout the year. Electricity consumption in the country in 2021 amounted to 500,209 GWh, corresponding to a 5% increase in energy consumption compared to the year 2020 (EPE, 2020) [9].

Electricity consumption has been increasing in Brazil. In homes, this increase occurs in two periods of the year: summer and winter. This is due to the use of air conditioning (summer) and electric showers (winter) by the population in these periods. The average consumption of electricity in Brazilian homes was 152.2 kWh/month [10], where the southern region has the highest consumption. However, this consumption may vary due to the greater occurrence of rainfall and milder temperatures, reducing the use of electricity. Linked to this, the use of renewable energy sources such as solar energy can further reduce energy consumption in homes.

In addition, the use of solar energy as a source of energy generation can help reduce the user's electricity bill. According to research carried out by Intelligence in Research and Consulting, about 46% of the population spends more than half of their income on electricity bills [11], placing Brazil in 10th in the ranking of countries that consume the most energy [12]. Therefore, the use of photovoltaic panels to generate energy in homes as a primary source, that is, homes powered by solar energy in its entirety, shows promise in both environmental and economic aspects.

Solar energy works by converting the energy received by the sun into electrical energy. The solar panel (photovoltaic plate) is composed of photovoltaic cells and works from the photovoltaic effect generating direct voltages and currents. This effect is due to the movement of electrons in the presence of light energy into the cell composed of silicon and absent of electrons, creating an electric current. Therefore, the solar panel can be understood as a source of current that depends on solar radiation [13].

Given the above, it is necessary to catalog the benefits of using solar energy as a way of generating energy in homes to assess the feasibility of using this type of energy in a primary way. The present study aims to analyze, from the literature, the use of photovoltaic panels in homes as an alternative energy source to conventional means of great economic and environmental impact. In addition, the cost benefit of using solar energy in the domestic context.

II. BIBLIOGRAPHIC REVIEW

Solar energy is an inexhaustible source of energy, as the timescale of life on Earth must be considered. The sun is an ordinary star that radiates energy due to the nuclear fusion reaction

of hydrogen atoms forming helium, therefore, the sun is one of the most beneficial energy possibilities for humanity [14].

The sun is the largest celestial body in the solar system, with a mass of 1,989x10³⁰ kg, representing 99.8% of the total mass of the solar system (composed of the sun and all the celestial bodies that orbit it). The radius of the sun is about 695 km, about 150 million kilometers away from the earth. In addition, it is mainly composed of hydrogen (91%) and helium (8.9%) The temperature of the sun's core is about 15,000,000°C, while on the surface it reaches 5,500°C [15].

The origin of most existing energy sources is from this star (the sun) to the earth, we can mention hydroelectricity, which occurs by evaporation and is responsible for the water cycle, thus damming the next generation. Wind energy, on the other hand, comes from the wind, through solar radiation that causes a large atmospheric circulation. Likewise, energy from biomass (firewood, charcoal, alcohol, etc.)

The sun radiates enough energy to Earth to meet 10,000 times the world's annual energy consumption and generate approximately 1,700 kilowatt hours of electricity per square meter per year. On the other hand, the availability of solar radiation depends on the latitude of the region, as the movement of the Earth around the Sun is described by an inclined plane at 23.5° from the equatorial plane [16].

There is radiation in all regions of the spectrum. However, the human eye is sensitive to less than an eighth of this radiation, which is around 400 to 750 THz (400 to 750 nanometers) – the visible region, which is narrow. However, the Sun holds 45% of all energy. The power density of solar radiation is called the solar constant and has a value of approximately 1360 Wm². This density represents watts per square meter (energy flow) and varies according to the distance between the earth and the sun [17].

Taking this context into account, the definition of a photovoltaic energy system is made from the understanding that this system is composed of one or more photovoltaic modules, and a set of equipment, such as batteries, charge controllers, inverters and some protection equipment. These devices may vary by application. Photovoltaic systems contain solar cells that convert solar energy directly into electricity. Every solar cell has a layer of semiconductor material in its composition. When solar radiation falls on a solar cell, an electric potential (voltage) is developed between the layers of semiconductor material. This potential is responsible for the current flowing through the external circuit when the external circuit is closed [18].

Photovoltaic technology can be installed in almost all regions of the world. As they contain no moving parts, these systems operate silently. The lifetime of a photovoltaic system is typically 25 years [18].

Photovoltaic systems can be installed close to large energy consumer centers and connected or disconnected from the grid in a centralized or decentralized way. They can power small or large applications. In this context, the application of photovoltaic systems can be divided into: autonomous systems (OFF-GRID) and systems connected to the grid (ON-GRID) [18].

It is necessary to consider that systems not integrated to the grid have batteries that store the generated energy, this is not necessary in integrated systems, because in these cases the excess generated energy can be transmitted to the grid and located elsewhere [19].

In an OFF-GRID system, all the energy generated is stored in batteries, ensuring that the system meets demand even in periods of low sunlight, and it works as follows: the system captures sunlight from photovoltaic panels to generate electricity at from

direct current, which is passed by the charge controller responsible for protecting the battery from deep discharges and overloads, all this energy will be stored in a set of batteries, then it will convert it from DC to AC through an inverter of frequency, and only then will it be used for Consumption [20].

In this way, photovoltaic solar energy is a source of renewable energy into electricity, solar cells convert solar energy into solar energy, photovoltaic systems are connected to the grid and spread in the form of micro and small power plants that can increase the supply of electricity while helping to maintain our energy. The renewable character of the matrix, in urban areas directly connected to the low voltage network, generates electricity and reduces the cost of generation, attracting the final consumer [21].

In addition to increasing the availability of electrical energy and environmental benefits, since the process of generating solar energy does not generate waste, the development of solar technology, in addition to boosting the national economy, has also generated many job opportunities and trained professionals well capable form of energy, because it does not release residual heat, does not alter the balance of the biosphere, does not involve burning fuel, does not produce any type of pollution, has a useful life of more than 20 years, requires little maintenance, is very simple and easy to install, and does not cause environmental impact, completely avoiding the greenhouse effect [21].

However, despite the many advantages of photovoltaic solar energy generation, the development of any energy source will bring changes. Thermoelectric power plants use toxic liquids, occupy a large area and alter the environment. Despite the negative effects, renewable energy is clean AND clean. Another disadvantage of being safe in relation to non-renewable energy sources is the high cost of investment in installing solar power plants [22].

III. MATERIALS AND METHODS

The present work has as a method the literature review that seeks to aggregate and synthesize the scientific knowledge already produced on the selected theme.

Explaining the method includes introducing the set of operations used, from the search for material, explaining the method, to the procedures used.

As for its nature, it is a theoretical work insofar as it is not a specific case study, but rather an analysis of a topic with the aim of enriching scientific knowledge on this topic.

A researcher's objective may be to develop new theories, create new theoretical models or establish new working hypotheses in various areas of human knowledge through deduction, induction or analogy.

The aim of this work is not to use the results in practice, but to enrich scientific knowledge and is therefore defined as theoretical research. It should be noted that the theoretical basis is the basis for the development of any type of research and the advancement of any scientific field.

As for the objectives, it was an exploratory study that, according to [23], "was designed to make the problem more familiar, with a view to making it more specific or building a hypothesis".

As for the methodology, qualitative research was used, characterized by the absence of quantitative data in the analysis.

In qualitative research, a deeper analysis of the phenomenon under study is carried out. Given the superficial nature of quantitative research, qualitative methods aim to highlight features not observed through quantitative research.

As for the form of the method, bibliographical research will also be used, that is, carried out from literature, contemporary or retrospective, considered of scientific validity.

With regard to technical procedures, the study used bibliographic data and literature analysis, as the work was carefully prepared from material already published, mainly books, opinions, articles, periodicals and materials available on the Internet.

Thus, this study was carried out using a bibliographic database such as information from articles obtained in the Google Scholar search engine (<https://scholar.google.com/>) with research related to the axes shown in Table 1. For the search engine, the words used in axis 1, 2, 3 and 4 were used together in the search for studies related to the research theme.

The search in the bibliographic database Periódicos CAPES was carried out for axis 5 and 6 for Scopus with axis 7. In the search engine and in the databases, there was no delimitation of publication dates, order by relevance, language definitions or filtering of results.

Table 1: Axes used for the research.

<i>Scholar Google</i>	Axle 1	Photovoltaic panels
	Axle 2	Residences
	Axle 3	Power generation
	Axle 4	Use of photovoltaic panels in homes
CAPES periodicals	Axle 5	Photovoltaic panels
	Axle 6	Residences
<i>Scopus</i>	Axle 7	Photovoltaic panels

Source: Authors, (2022).

The studies selected in the search were organized by relevance, where the results of the researched studies were checked for the choice of articles and works that were related to the theme of the present study. Among the selected results, scientific articles published in magazines or abstracts published in conference proceedings on solar energy, course conclusion works and master's dissertations were used.

The research aimed to deepen the scientific knowledge on the subject, characterizing itself as a basic research. It is of the descriptive type, based on theoretical subjects contained in books, articles and academic works for its literature base. This study is

based on the type of bibliographical research which consists of collecting information from texts, books, articles and scientific materials. The collected material was used in the research in the form of quotations and references, serving as a theoretical basis for the development of the study. In addition, the generated study base served to compare information collected and finally produce conclusions on the chosen topic. The criteria for choosing articles and works to compose the bibliographic base of this study are arranged in the flowchart below. The process from defining the keywords to the articles selected for final discussion is shown.

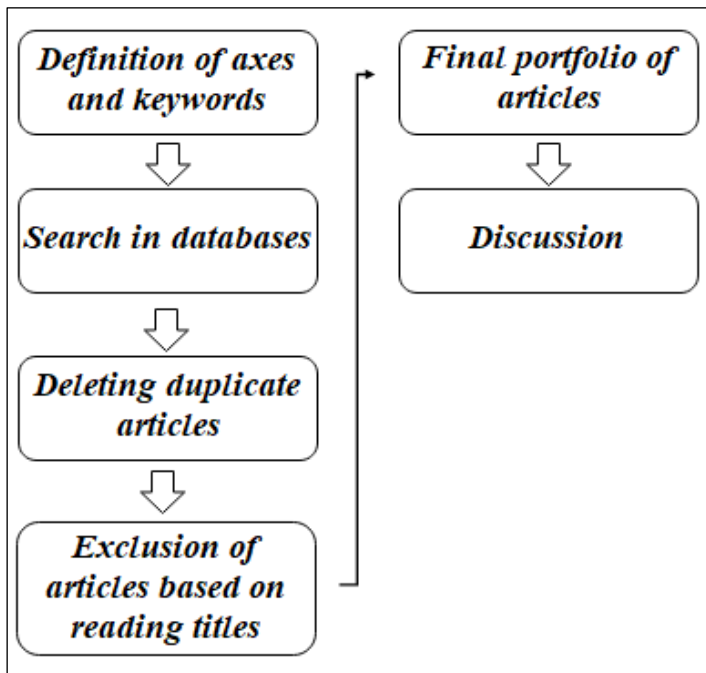


Figure 1: Flowchart used in the criteria for choosing the studies. Source: Authors, (2022).

IV. RESULTS AND DISCUSSIONS

IV.1 PORTFOLIO SELECTION

Through the selection of studies to compose the research, it was possible to acquire articles from the electronic database divided between the bases shown in Table 1 and presented in the graph in Figure 2. The graph qualitatively shows the division of articles by database. It is noted that the Scholar Google and Periódicos CAPES databases presented a greater number of selected articles.

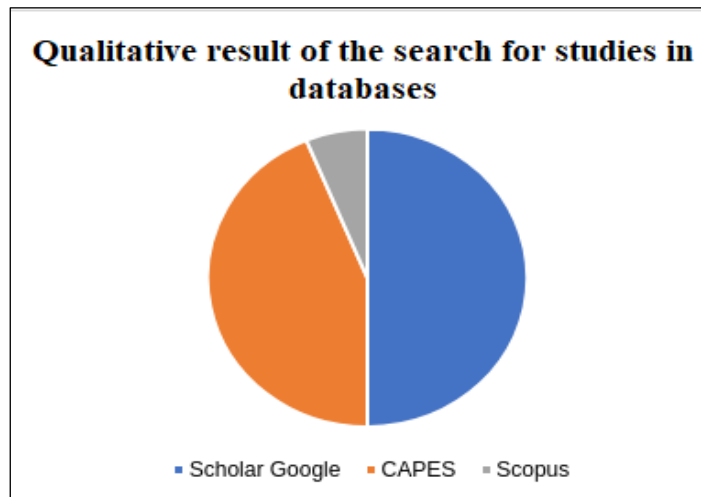


Figure 2: Graphical representation of the result of the search for studies in the databases. Source: Authors, (2022).

Based on the criteria defined by Figure 2, a total of 15 articles were selected and saved in separate named folders with the corresponding database. Table 2 shows the number of articles obtained by database.

Table 2: Number of articles obtained from the research databases.

Data base	Total articles
Scholar Google	7
CAPES periodicals	7
Scopus	1

Source: Authors, (2022).

Table 3 summarizes the works selected in the databases that make up the study's portfolio. The abstracts show the main results obtained by the study, the year of publication, the method used and the objectives.

Table 3: Summary of selected studies in the databases by title/year, method used, objective and results achieved.

Title/Year	Method	objective	Results achieved
Cost comparison between photovoltaic solar energy and conventional sources (2006) [24]	Literary discussion on aspects of the cost of installing photovoltaic panels and conventional forms of power generation	Demonstrate comparisons between the cost of installing solar energy sources and other conventional sources for a national panorama	Use of energy powered by solar panels is efficient, however, the value to develop a solar system is much higher than the value for a hydroelectric plant
Photovoltaic solar energy as a complementary source of electricity for homes in the pursuit of sustainability (2008) [25]	Use of data from photovoltaic systems installed in Florianópolis - SC for the year 2007 and estimates for other Brazilian cities, in addition to using the demand curve.	Analysis of the energy generation potential from photovoltaic panels in Florianópolis - SC, Brasília - DF and Fortaleza from a 1 kWp power installation based on model scenarios from developed countries	The demand curve in Florianópolis and Brasília showed a similar behavior, while in Fortaleza the curve is more linear (greater use in the daytime period)
Integration of photovoltaic solar panels in residential buildings and their contribution in a mixed urban zone energy feeder (2009) [26]	Kits installed on roofs of residential buildings in a mixed-use neighborhood in Florianópolis - SC were used.	Evaluate how a photovoltaic system integrated in buildings can contribute to the energy available in an urban power grid	The kits contributed to the financial return with an average of 25 years along with the coverage areas of the city
Application of photovoltaic panels in homes: case study in Guaratinguetá and Seville (Spain) (2012) [27]	Installation of photovoltaic stations in residential for case study in both cities	Potential for installing a photovoltaic system in a house in order to reduce electrical consumption	For Seville, the value of installing the panels would be amortized in 8 years and for Guaratinguetá in less than 4 years
Application of photovoltaic solar panels as a complementary source of electricity in homes (2013). [28]	It used the calculation of the energy balance between generation and production for a real consumption curve and verified current tariffs and economic-financial viability.	Solve installations and network connections of a photovoltaic solar system, predicting costs based on available technologies.	Great potential for solar energy throughout the entire Brazilian territory and demonstrated the behavior of the system for residential consumption.

Title/Year	Method	objective	Results achieved
The use of photovoltaic energy in Brazilian homes: an implementation analysis (2013) [29]	Bibliographic survey and consultation in books and magazines in virtual and written collection	Present discussions regarding the implementation of renewable energy sources	The cost of implementing photovoltaic systems is still not viable for collective use
Technical and economic aspects of residential use of photovoltaic panels connected to the grid (2013) [30]	Installation of a PV system for a residence in the city of Curitiba: case study	Present the main technical and economic aspects regarding the use of photovoltaic panels in homes	Return on savings for a grid-connected system varies between 10 and 13 years and may decrease in the short term
Influence of urban configuration on photovoltaic generation with systems integrated into facades (2013) [31]	Exploratory study of different urban sites with potential for energy generation using parameters and urban scenarios with the Rhinoceros program	Evaluate the application of photovoltaic panels in different urban settings	The potential for installing PV panels is due to parameters such as: solar accessibility and height of buildings
Economic feasibility of installing photovoltaic panels in a residence in the city of Caratinga - MG (2016) [32]	Installation project of photovoltaic panels in medium-sized residence	To analyze the feasibility of installing photovoltaic panels in a medium-sized residence in the state of Minas Gerais	The project proved to be viable with cost-effectiveness accepted and considered by the owner of the residence.
Economic viability of using solar panels in the horizontal condominium Bela Vista: Case study (2016) [33]	Interviews were carried out in the condominium about the average monthly energy consumption and the use of equations for panel sizing	Show the economic viability for the implementation of an energy generating system using photovoltaic panels in a horizontal condominium	The use of solar energy is a viable system capable of meeting the energy demand of the residence.
Use of photovoltaic panels in homes (2019) [34]	Search on the Google Scholar platform for articles, books and scientific documents	Bring concepts of sustainability, world and national panorama of energy production	It showed the importance of using photovoltaic panels in global and local sustainability, however it presents difficulties in obtaining
Implementation of autonomous power generation systems for the semi-arid region of Paraíba (2019) [35]	Assembly of systems and equipment according to methodologies of other articles	Evidence of the operation of three autonomous energy generation systems in homes, including solar energy	Solar incidence helps not only the solar energy generation system but also the electrochemical reactor.
Economic impacts of expanding the use of residential solar energy in Minas Gerais (2019) [36]	Uses regional model built for Minas Gerais with structural equations and parameters detailed in other articles	Simulate the impacts of using photovoltaic energy in homes in Minas Gerais on the local economy	The adoption of photovoltaic panels impacts several sectors and would cause a relative increase in the consumption of financial services
The application of clean technologies for sustainable urban development through the deployment of photovoltaics (2021) [37]	Deductive method of bibliographic review on the subject in magazines, publications, dissertations and among others	To present how it is possible to apply clean technologies in sustainable urban development by applying solar energy	The deployment of PV panels show promise in the use of clean technologies, however government incentives are needed
Cost and benefit of photovoltaic panels in residences in Rio de Janeiro (2022) [38]	Case study that uses economic and financial indicators to analyze the cost-benefit of installing photovoltaic systems	Analyze the cost-benefit ratio for the implementation of a photovoltaic system	Costs with electricity are reduced even though the initial expense is high, containing a quick installation system, clean energy generation and without emitting pollutants into the environment

Source: Authors, (2022).

IV.2 PORTFOLIO DISCUSSION

Based on the 15 articles of the final portfolio, the works are discussed so that the feasibility of using photovoltaic panels in the generation of energy in homes can be explored from the perspective of economic, social and environmental factors.

IV.2.1 Operation of Photovoltaic Panels

Solar energy can be obtained through the photovoltaic effect, from semiconductor materials, that is, materials with a conductivity value that are between insulators and conductors. The conductivity of a material is a microscopic property that indicates a great ability to easily carry electrical charges. In addition, they have a valence band and conduction over an energy interval less than or equal to 3 eV [28].

The representation of semiconductors is given by silicon doping. By adding to the intrinsic crystal that has 4 electrons in its valence layer, the behavior of the material is modified and it becomes a conductor. Doping silicon with an element such as

phosphorus results in a free electron in its conduction band. This process characterizes an N-type semiconductor material, also known as a negative electric charge carrier. By adding an element with 3 electrons in the valence layer, we have a carrier of positive charges characterizing a P-type semiconductor material. P-type and N-type semiconductor materials are electrically neutral. By joining both materials, you have a P-N type joint. For this junction, the free electrons from N move to P and with this movement the initially neutral semiconductors generate a negative electric potential in P and a positive one in N. This movement occurs in order to create an electric field and establish an equilibrium electric. Such value of electric field that needs to be generated in order to create an electric balance is what determines the gap value, that is, a value of energy at which an electron crosses the junction. All this movement to fill the gap and the conduction band is the process of generating electrical energy. When exposed to the incidence of photons of light, that is, sunlight with energy greater than the gap value, electrons are stimulated to jump to the conduction band, generating the energy that is collected by the conductors [26]. Figures 3a and 3b illustrates how photovoltaic cells work.

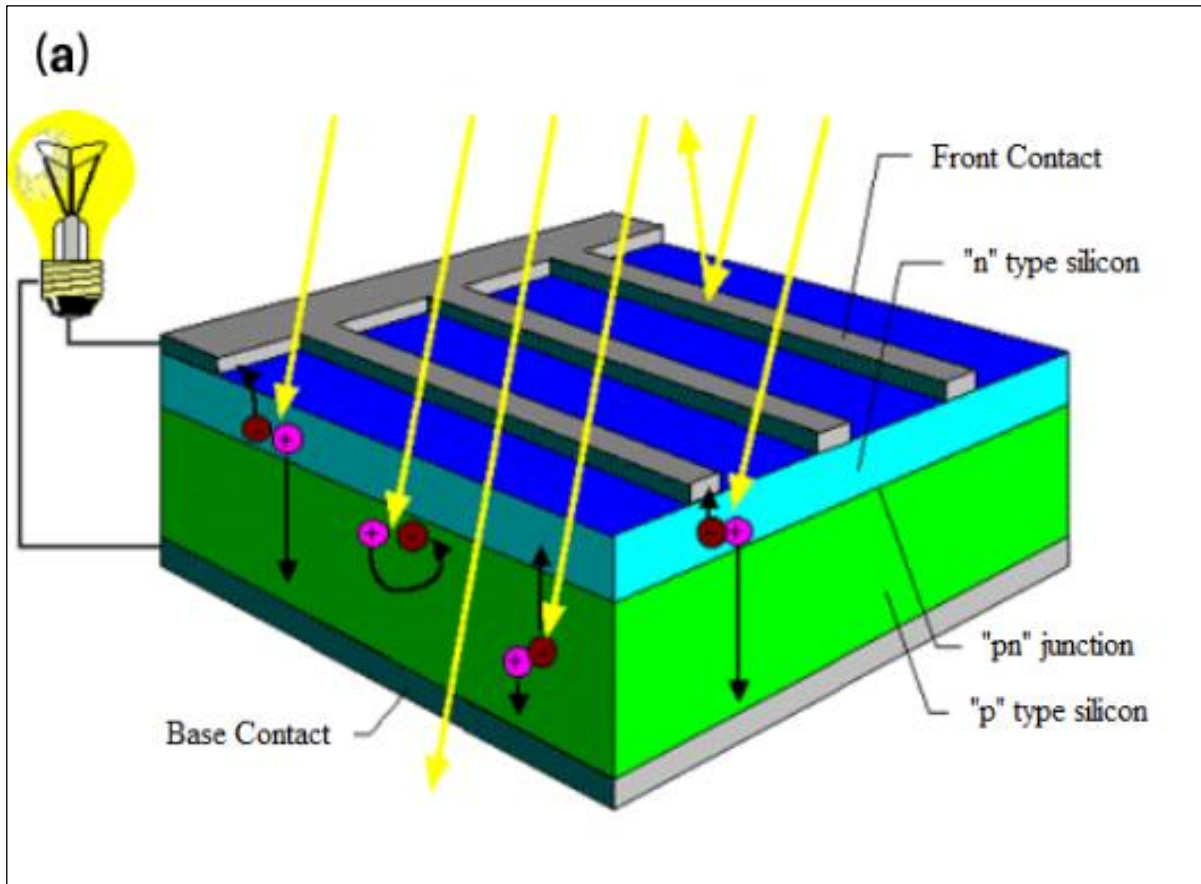


Figure 3a: Operation of a photovoltaic cell. Cross section of a photovoltaic cell. Source: [22].

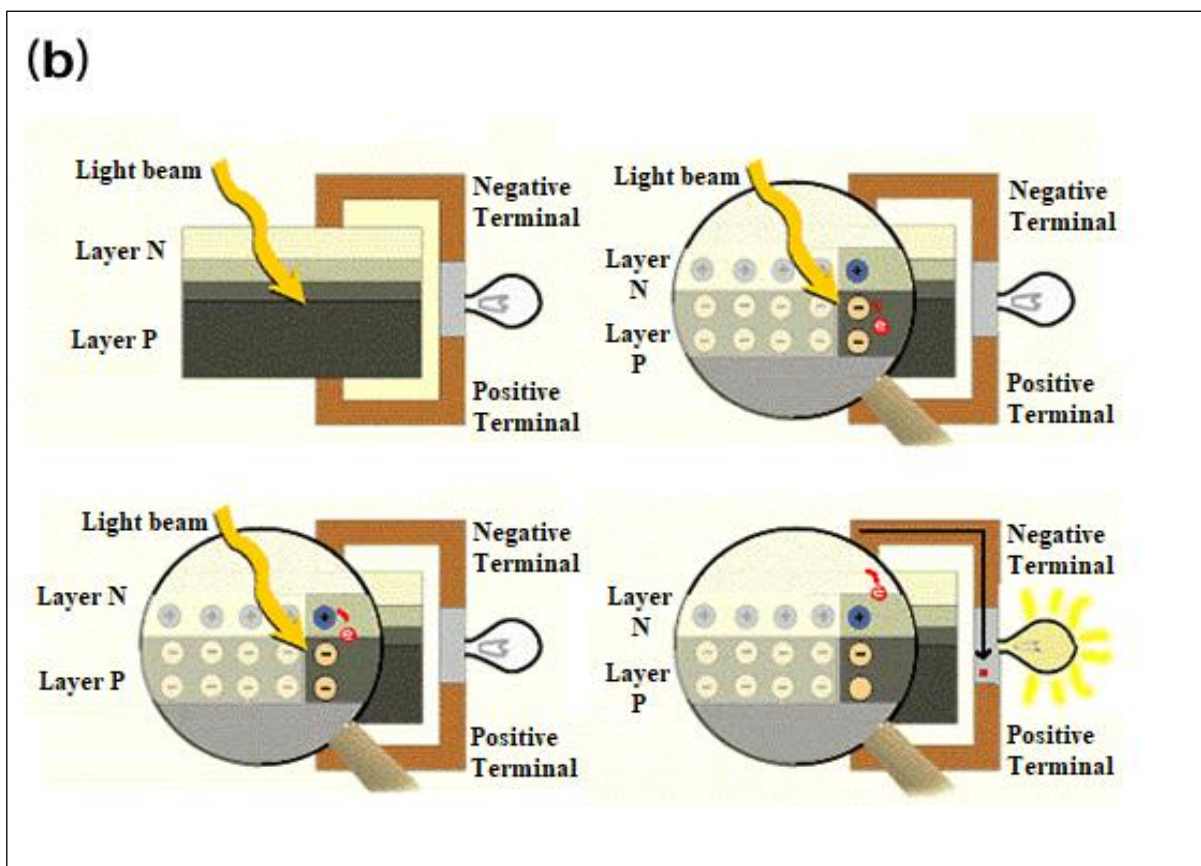


Figure 3b: Operation of a photovoltaic cell. Photovoltaic effect at the P-N junction. Source: [22].

IV.2.2 Installation of a Photovoltaic System

A photovoltaic system consists of: (a) photovoltaic generation modules, (b) wiring, (c) solar panels, (d) converter system, (e) protections and (f) connections. You can install

photovoltaic systems in two ways, which are isolated or connected to an electrical grid. Separately, they serve places such as homes that are far from the public power grid. The other way is the installation with the connection of the modules to the conventional electrical network, integrating the modules in buildings [26].



Figure 4: Composition of the photovoltaic solar system connected to the grid.
Source: CSR ENERGIA SOLAR, (2008) [39].

IV.2.3 Use of Photovoltaic Panels in Homes

The interest in implementing a photovoltaic system in homes lies in the ability to generate energy using a renewable and clean source as fuel, since commercial and residential buildings capture about 50% of the electricity consumed in Latin America. This would imply a decrease in the use of energy generation powered by burning fossil fuels that are harmful to the environment.

The [25] demonstrated through power generation data and the use of two photovoltaic systems for three locations the demand curve of residences. The results showed that these curves are variable and depend on factors such as consumption habits, occupancy rate and energy use at times with larger family residences.

Furthermore, due to the variability of solar incidence in Brazil, the operation of a photovoltaic system will be proportional to the availability of solar radiation, and there may be a need to use the local electrical grid.

With regard to solar availability, studies are carried out in the region of the Brazilian territory with the greatest potential for using solar energy. Thus, [35] used autonomous technologies for power generation, including the use of solar panels for the semi-arid region of Paraíba.

The system proved to be useful for use in condominiums that want to use clean energy in more general energy demands, in order to reduce costs such as electric fences, automatic gates, blackout prevention, among others.

The [33] showed the economic viability of implementing a system for power generation using solar panels in a horizontal condominium. By means of equations, the dimensioning of the system was done in addition to research to obtain the electrical

demand of the residents. One of the objectives of the project was also to analyze the replacement of the energy matrix partially for periods where there is no use of solar energy, such as at night. The implementation of the system proved to be a viable alternative with a useful life of 25 years.

The use of energy generation by photovoltaic panels is also analyzed in buildings. [26] developed a study on the applicability of a system of photovoltaic panels connected to the electrical grid and integrated into buildings, analyzing the contribution of this type of energy generation in residential buildings in urban areas. The study used kits installed on the roofs of buildings in a mixed neighborhood in the city of Florianópolis - SC.

It was concluded that the roofs had a high potential for energy generation when installing the kits in the sunniest part of the roof. In addition, they showed the contribution of kits, since the peak of energy generation corroborates with the peak of consumption of buildings, whether for commercial, services and residential demand, since it is a mixed neighborhood.

The [40] showed, through a bibliographical survey, an overview of the implementation of photovoltaic energy in homes in the Brazilian territory. The authors showed that the use of energy sources becomes urgent in relation to the growing energy consumption in homes. In 2009, average consumption was around 150 kW/h per month and rose to 153 kW/h per month in the following year, representing an increase of 1.1% according to [16].

These values show the proportionality of energy consumption to the increase in population, that is, with the increase in population, the demand for energy must be proportional, and the contingent can increase by at least ten million.

The [32] analyzed the economic viability of deploying photovoltaic panels in homes by assembling a photovoltaic system in a home. The system was free of interferences such as buildings

that generated shadow and disabled the functionality. Power generation by this means proved to be feasible with an estimated time of 10 years for the user to enjoy the electricity generated by the system at no extra cost. The generation of energy by photovoltaic panels is directly linked to the concept of sustainability. The search for an energy source that can supply the energy demand while not harming the environment for the next centuries, as well as generations, is the objective of several nations.

The [34] sought to conceptualize sustainability inserted in energy production based on a survey of documents, articles and books. They showed that the word is related to energy production due to the possibility of obtaining energy from an independent, inexhaustible and non-polluting source. This source would bring benefits to the global energy matrix.

IV.2.4 Investment Cost

Another determining factor in the use of this type of power generation is its investment cost. Studies have tried to estimate the economic impacts of using renewable energy sources [41-43]. Costs are considered in three main items: photovoltaic panels, inverter and the system of equipment involving mechanical structures, electrical equipment, cables for connections in addition to the general implementation costs [40].

According to ANEEL, to meet the demand of a family, the system's generation power must be 29 kWh in 8 panels, resulting in the cost of R\$ 19,900 to install these kits. This cost makes photovoltaic technology still not very viable and expensive for a low/medium income family, since the government does not provide assistance in obtaining this system. Furthermore, the incidence of a high tax burden makes installing the system even more expensive than in other countries.

According to [40], a family that consumes up to 528 kW/h would have to disburse almost R\$ 50,000. This is possibly the biggest barrier to the extension of this technology.

The [40], quoted the investment required to obtain the components of the photovoltaic system without including the cost of installation.

Table 4: Cost of equipment without installation price.

Kits	KW/h power	Cost (BRL)
1	29.38 KW/h month	BRL 2,7560.00
8	235.04 KW/h month	BRL 19,932.00
18	528.84 KW/h month	BRL 46,608.00

Source: [44].

Table 5: Cost of equipment without installation price.

The amount	equipment and installation
14	Mitsubishi 255W Premium Solar Photovoltaic Panels
1	Out Black Charge Controller 80-48V – 3840W
1	Inverter Out Black – 3.6 W – GUF 3648
1	Flex Ware Surge Protector
1	Mate System Display and Controller LCD 4-in.
4	Moure Clean 220 AH Stationary Battery
Total	BRL 42,435.00

Source: [45].

Tables 3 and 4 show the quotation on the websites. For families that spend more than 500 KW/h per month, the total value is shown in table 4. It is observed that the value is still high and with the possibility of being an even higher value depending on the size of the residence and the demand of the family composition.

The [36] sought to analyze the impacts caused by the use of renewable energy for a set of families, showing the difference between different family groups in the state of Minas Gerais. The study performed economic and technical feasibility analysis for determining the energy conditions for the use of solar energy. They obtained that the use of solar energy is capable of causing impacts in different sectors depending on the family composition.

The [30] analyzed the technical and economic characteristics through a case study for the installation of photovoltaic panels in a residence located in the city of Curitiba. The payback time was around 10 years, with factors that may shorten this period, such as the implementation in Brazil of a sales system that allows the sale of the surplus generated. This system is also used in other countries, Germany for example.

However, comparing the cost between energy generation sources, it is observed that sustainable alternatives have a higher final price than alternatives more used as conventional sources [24].

The [38] carried out a case study on the installation of photovoltaic panels in a residence in Maricá in order to analyze the long-term cost-effectiveness of using this form of energy generation. They used economic and financial indicators for this analysis, such as: Net Present Value (NPV), Internal Rate of Return (IRR), Return on Investment (ROI) and Payback. These indicators infer the relationship between costs and benefits of installing photovoltaic panels. They used data provided by a company that provides photovoltaic panel installation services in Rio de Janeiro.

The study showed that the use of alternative energies was important in reducing expenses related to energy consumption. Table 5 shows the study budget. It is observed that the system requires a high initial cost, however, the amount spent is offset by the decrease in what is spent on electricity. According to the result obtained from the analyses, from the third year it is possible to obtain savings with the generation of energy used.

Table 6: Financial viability analysis.

Factor	Value
Investment value	BRL 26,968.00
Annual energy readjustment	7%
Service life of the photovoltaic system	25 years
Payback (payback time)	3 years
Return on Investment (ROI)	14 times
Internal Rate of Return (IRR)	41.52%
Discounted NPV (25 years and SELIC rate)	BRL 136,564.00
Total accumulated savings (25 years) = BRL 415,782.33	

Source: [38].

V. CONCLUSION

The present work sought to demonstrate, through bibliographical analysis, the use of photovoltaic panels in residences as a source of alternative energy generation to conventional means, widely disseminated nationally and worldwide. The use of solar energy in Brazil is still not widespread, even though it presents excellent conditions for this type of technology. The current energy matrix of the Brazilian territory is concentrated in the use of hydraulic energy, representing about 84% of the proportion of forms of energy generation. Worldwide, the large portion is concentrated on the use of energy generated by burning fossil fuels and only a small portion is represented by solar energy. Solar energy can have a great contribution in the generation of electrical energy for residential consumption and for other

purposes. The study showed the feasibility of using this form of energy generation as a potential replacement of the energy matrix in Brazilian homes. However, this form of energy generation still has a high initial investment cost, and the cost of implementing this system may be at least 5 times more than the expenditure on a conventional electrical network. In this way, it is necessary to encourage the government through public policies for sustainable development, focusing on the dissemination of the use of solar energy, in addition to reducing taxes for those who use this technology and the possibility of selling surplus energy.

In addition, with the reduction of the price of this technology as it evolves, they make possible the economic viability of this technology and boost its use in the residential area.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

Methodology: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

Investigation: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

Discussion of results: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

Writing – Original Draft: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

Writing – Review and Editing: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

Resources: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

Supervision: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

Approval of the final text: Chandley Christopher Gimack da Rocha, Emiliano Augusto Reis Corrêa and Paola Souto Campos.

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