Design of an Anti-theft Alarm System for Vehicles using IoT

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Abstract—**Automobiles have become one of the most sought-after targets for criminals due to their worldwide popularity. Crime is reflected in the statistics, which show that over the years, the crime rate of vehicle theft has been on the rise. As part of the fight against this crime, the vehicles come with certain systems incorporated to avoid this type of situations; obtaining many outstanding results. In this research project, a system was developed that allows through the application of the Internet of Things (IoT), the management of software and hardware technologies that allow the user to have access to various actions, such as vehicle location through the global positioning system (GPS), and identification of the offender, through radio frequency identification (RFID), as well as the global system of mobile communications (GSM). The objective of the research is to design a mobile and IoT application to reduce robberies in the department of Lima-Peru, using the scrum methodology. The result obtained is the design of the mobile application, with its anti-theft system, vehicle blocking and notification of unauthorized ignition.**

Keywords—*Global mobile communications system; global positioning system; internet of things; radio frequency identification; scrum*

I. INTRODUCTION

Since its inception, the automobile has played a very important role in the industrial field, which has been demonstrated by a steady increase in its production and sales. Thus, in India, it is observed that the number of vehicles purchased has reached 100 million units, and it is expected that this figure could reach 450 million by 2021. Likewise, in the United States (US) [1], the picture is not much different as the number of people with driver's licenses is much lower than the number of cars.

However, this boom in the production of motor vehicles has brought with it the appearance of people who seek to obtain them illegally, regardless of the fact that some of them have protection systems, which so far have not been sufficient to stop this type of behavior [2]. Now, this increase can be seen reflected in the country of Mexico, where the percentage of vehicle theft has increased by 27.5% during the first half of 2020 [3]. Similarly, in our country the situation does not vary [4], since in the department of Lima the increase in vehicle theft complaints has been increasing from 3% to 27% in the period of time between 2017 and 2019 according to figures provided by the National Institute of Statistics and Informatics (INEI).

Likewise, this type of activity has intensified in the search for ways to avoid the systems with which the vehicles are equipped, since most of them only have GPS location systems [5], so these criminal gangs have implemented a system whereby they block these signals in certain strategic locations, thus gaining an advantage in their actions.

Now, the systems that use IoT technologies provide us with a series of options such as being able to visualize the status of the peripherals that the vehicles have, in this sense,According to the author [6] can know when the headlights are turned on or that the vehicle's engine has been started; all this through notifications to mobile device. Likewise, it is possible to implement systems that, after the vehicle is started, initiate a monitoring process by means of GPS signals, which allow the owner to know the location of the vehicle in real time. Similarly [7], the IoT allows the owner to interact with this system by remotely turning off the engine.

Indeed, the IoT allows systems to provide many more options to suit the needs that users have, for example, the implementation of vehicle security systems that have the ability to monitor by silent video surveillance unauthorized persons inside the vehicle, which not only prevents the theft of the vehicle, but can also identify the person who did it [8]. On the other hand, there are vehicle security systems with complex identification methods that raise the cost of their development and acquisition. However, the IoT allows different devices, such as RFID tags that are low cost [9], can be used in the identification and operation of these systems with which it becomes a viable option for those who have the need to create such systems and have low economic resources.

This research has been developed taking into account the various factors that IoT technology has, in this sense, an anti-vehicle theft system that manages the different actions of identification and action within a vehicle by means of IoT was carried out.

The objective of the research is to design, through a mobile application, an innovative vehicle security system through which it is expected to reduce the percentage of cases of people who suffer the theft of their vehicles in the department of Lima-Peru.

Then, the following points was developed in the paper: in Section II the literature review where analyze those works that served as a basis for the development of the research, in Section III on the methodology used during the development of the project and the steps that were performed, followed by Section IV the results that have been obtained at the end of the development of the project, then in Section V we develop the

theme of discussions where we analyze the similarities with other projects, finally in Section VI the conclusions and future work.

II. Literature Review

In this research a vehicle anti-theft system has been developed by applying IoT technology to control the different actions of the system, in order to reduce the rate of vehicle theft in the area of the department of Lima - Peru. In this sense, it has been taken into account other research works that have implemented technologies, which have been used in this work.

Thus, we see how [6] implements light and sound sensors inside a vehicle in order to know the state in which it is; this information is centralized in an Arduino Mega 2560 device. Then, by means of a 3G-Shield, this information is transmitted to the user for its respective visualization. As a result, the user can remotely visualize the status of the headlights (on, off), the doors (open, closed), the saloon light (on, off) and the vehicle's engine (on, off). In short, the user can become aware of his habits with respect to the state in which he leaves his vehicle after use.

However, [7] addresses the problem of vehicle theft through the implementation of GSM and GPS technologies. Consequently, IoT is used to communicate with the user by notifying him that his vehicle has been forcibly started and also initiates a constant report of the vehicle's location. Then, the user can interact with the system allowing him to turn off the vehicle by sending a text message which will be received by the system and will trigger the vehicle to stop. In conclusion, the user can access this way to a low-cost anti-theft system that allows him to locate his vehicle in real time, without the need to have specialized knowledge in the field of smartphones.

In addition, the author [8] implements a vehicle security system with video surveillance of the driver. Consequently, IoT is applied together with a biometric driver identification system, which aims to prevent unauthorized persons from operating the vehicle. However, the system adds the functionality to identify the person who tries to perform such action by means of real-time video surveillance of the driver's cabin. In short, the vehicle owner can identify through silent video surveillance any person driving his vehicle, all this through a low-cost system.

However, in [9] the author's problem is that security systems are expensive and cannot be implemented in two-wheeled vehicles. For this reason, a low-cost system is developed that implements the recognition of the driver by means of an RFID tag, which allows the system to turn on the vehicle. A GPS location system is also used, which is visualized by means of an application installed in the owner's cell phone. As a result, the system performs the identification of the RFID tag which allows the ignition of the vehicle by means of the key, then the vehicle can be monitored by means of GPS signals sent by the GSM device connected to the system's Arduino. In summary, it is possible to protect two-wheeled vehicles (motorcycles) with a low-cost security system that gives the location and the ability to identify the driver through RFID tags.

On the other hand, [10] mentions that in recent years with the growth of the global and national economy, vehicles have become a necessity for people and at the same time a great loss of money because of theft, criminals use the method of hot wiring to disable the anti-theft system that comes as part of the vehicle, so they designed a system that turns off the engine when the thief starts the vehicle and can capture the image of the offender when starting the vehicle, so they had to use Arduino, relay, GPS and a camera, to develop the system. As part of the results, all the tests were 100% effective. Finally the results showed that the system worked correctly and efficiently.

Finally, the authors provided very interesting research, helping to complement the research conducted, however, in the research implemented a more innovative system, which is helping drivers of vehicles in Lima.

III. Methodology

For the development of this research project, made use of an agile methodology in conjunction with various tools both in the field of software and hardware. In this sense, the project was developed based on the Scrum methodology, which was detailed later, and also mention which are the technological tools that allowed to implement the system in conjunction with the various electronic devices.

A. Scrum

This is known as one of the best methodologies, but it is actually an agile project development framework [11], as shown in Fig. 1 presents each of the stages and the order they take during the application of the same in a project. In addition, it has principles which allow satisfying customer needs, being accessible to changes in requirements, having a collaborative environment between the development team and customers, regular delivery of progress, reflection on how to improve the errors that can be found [12]. The following is a brief description of each of the stages that make up this framework:
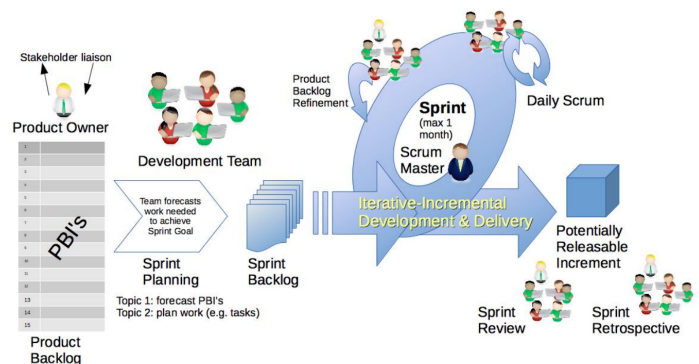

Fig. 1. Scrum Methodology Process [13].

1) Determination of Roles: This is the first stage in which the team as a whole must assign roles within the project development, such as the Product Owner, the Scrum Master and those who was part of the Development Team [14].

2) Planning: At this stage, the team must determine which are the tasks to be developed, in this sense, several meetings are held to discuss each one of them [15]. In this way, a list of the tasks to be performed is obtained, which allows to estimate

each one of them and therefore to have knowledge of the period of completion of the project [16]. At this stage, each of the sprints to be developed is determined, which are considered as mini-projects within the overall project [11].

3) Development: Also, known as the implementation stage, its purpose is to develop each of the Sprints established according to their order of prioritization [14]. It must be taken into account that each of these Sprints must be carried out within the time frame that has been previously established [15].

4) Review and Retrospective: Upon completion of each Sprint, the project development team conducts an analysis to determine whether the project meets the requirements for approval [14]. Then, the team should determine which were the highlights and also those in which difficulties or failures were found, in order to help the team to improve.

B. Software Tools

As part of the development of the research project, the software technologies necessary for its correct development were taken into account.

1) Kotlin: To perform the programming of the application we make use of this system that is compatible with Android, in addition [17], this technology since it was created by JetBrains and Kotlin in 2010 has been characterized by its compatibility, performance and its learning curve.

2) Firebase: It is a service provided by Google through the cloud through which you can perform instant messaging, user authentication, real-time database, and many other functions [18]. However, it must be taken into account that the initial configuration of this service must be carefully carried out, so that all its functions can be used normally [18]. Fig. 2 shows how this medium allows data to be centralized and then distributed to different devices, as well as allowing several actions to be performed simultaneously [16].

3) Moqups: In order to obtain high quality prototypes that are understandable to the naked eye, the Moqups tool is used, which uses some of the services provided by Firebase, which is extremely convenient for compatibility in the development of the project.

C. Hardware Tools

In this section we mention which devices and hardware technologies have been used in the development of this research project.

1) RFID Reader: Within the concept of communication that is established in RFID technology we find the tag reader which fulfills the functions of transmitter and receiver, in such a way [18], the transmitter radiates electromagnetic waves which allow to feed the tags at the time of wanting to detect them and emits the information that was required.

2) RFID Tag: It is one of the emblematic elements of RFID technology due to its production characteristics, which include low production cost, compatibility in manufacturing materials and electromagnetic resistance to the environment in which it is located. In addition [18], there are different types and sizes, which are chosen primarily for their detection capability,

which can range from a few centimeters to 25 meters using microwave or UHF antennas.

3) Arduino: The Arduino is an electronic device in which various modules (GSM, GPS, RFID reader) and sensors (light, sound) can be connected to collect information and send on/off signals as needed [6].

4) GPS Module: This is a module whose main functionality is to provide the coordinates in which it is located, this can be sent to a system with Arduino device with which you can track it.

5) GSM Module: This GSM module has the characteristic of providing a means by which communication can be established with it, so, as this GSM technology has evolved, it has a greater coverage which allows a better availability in communication [1].

6) Camera Module: The camera module used for this project is the ESP-32 model, since it has features that fit the needs of the project such as: low acquisition cost, live video transmission, and ease of adaptation to the use of android applications for video transmission via the Internet.

D. Methodology Development

1) Determination of Roles: In this first meeting the roles were determined according to the capabilities of each of the members, Table I shows the different roles and the persons responsible for them.

TABLE I. DETERMINATION OF ROLES

Role	Responsibility
Scrum Master	Laberiano Andrade Arenas
Product Owner	Laberiano Andrade Arenas
Development Team	Jorge Arellano Zubiate Jheyson Izquierdo Calongos

2) Planning: Now, at this stage, the project development team determined which Sprints are required according to the project needs:

- Sprint 1: Implementation of the GSM system that allows the connection between the device and the mobile application. Table II shows the user stories that was developed in this Sprint.

- Sprint 2: Implementation of the RFID system that allows the detection and notification of forced starts in the mobile application. Table III shows the user stories that was developed in this Sprint.

- Sprint 3: Implementation of the GPS system that allows the location of the vehicle through the mobile application. Table IV shows the user stories that was developed in this Sprint.

- Sprint 4: Implementation of the camera system in the vehicle cabin for driver identification through the mobile application. Table V shows the user stories that was developed in this Sprint.
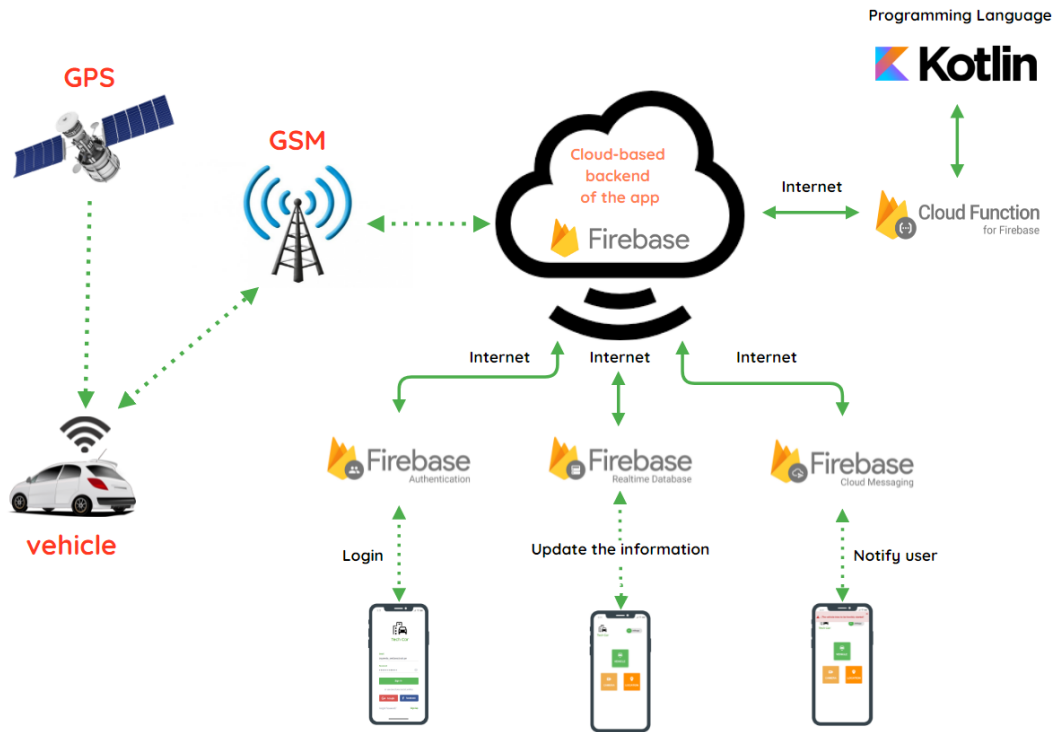
Fig. 2. Diagram of Firebase Operation.

TABLE II. Sprint 1 User Stories

User Stories
I as an administrator want to integrate a GSM device to obtain remote vehicle information.
I as administrator want to implement a server for remote connection to the vehicle.
I as an administrator want a status notification in the app to know the status of the vehicle.
I as an administrator want a registration module for the user to register within the system.
I as an administrator want a login module for the user to validate his login to the system.
I as an administrator want a linking module for the user to get the vehicle information.

TABLE III. Sprint 2 User Stories

User Stories
I as the administrator want to integrate an RFID tag reader to identify the tags.
I as an administrator want an electrical fluid blocking system to block the ignition of the vehicle.
I as the administrator want to register the owner's RFID tag to unlock the vehicle's ignition system.
I as the administrator want an RFID notification to let the user know when the vehicle was forced started.
I as an administrator want a main module for the user to have access to the main options.

TABLE IV. Sprint 3 User Stories

User Stories
I as the administrator want to integrate a GPS device to detect the location of the vehicle.
I as the administrator want to implement Google Maps to facilitate the location of the vehicle.
I as an administrator want a record of the locations so that the user can know the last location of the vehicle.
I as an administrator want a location module in the application to display the vehicle location information.

TABLE V. Sprint 4 User Stories

User Stories
I as an administrator want to implement a camera module to visualize the vehicle cabin.
I as the administrator want a video log so that the user can view who entered the vehicle.
I as an administrator want a usage acceptance module for the user to grant permission to use the vehicle.
I as an administrator want a video module in the application so that the user can view the video in real time.

3) Development:

- Sprint 1: As shown in Fig. 3, the different electronic devices that are part of the circuit of the research project were connected. Each of these devices fulfills

a function . as it allows the IoT concept to be applied. In addition, in this Sprint priority is given to obtaining information through the GSM module, which allowed us to make the remote connection between the Arduino and the mobile application. In this Sprint, the
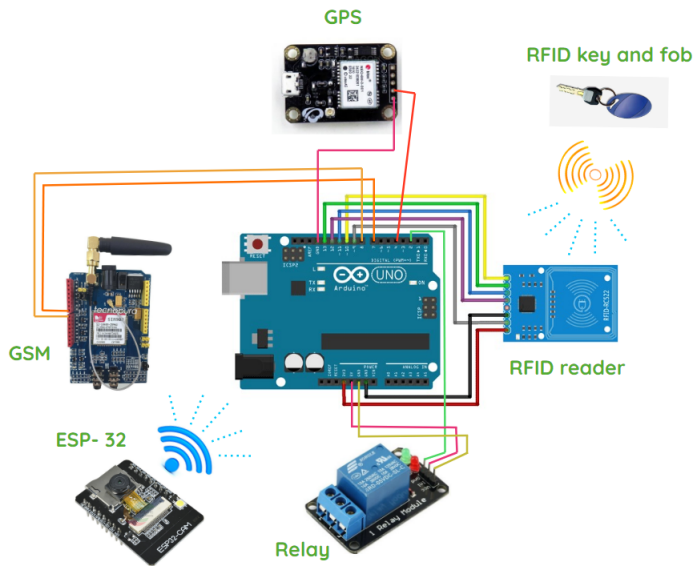

Fig. 3. Physical Diagram of the Anti-theft System.

Fig. 4. Diagram of GSM Module Operation.

remote connection between the Arduino circuit and the mobile application was implemented by means of a server that serves as an intermediary between the two. In this sense, the GSM implementation was carried out achieving the remote connection as shown in Fig. 4, where you can see the communication between both points through the server, which allowed us to obtain information on the status of the vehicle and perform the respective actions remotely through the cell phone.

In order for the user to communicate with the system, he/she must be previously registered with a user name and password. Fig. 5 shows the prototype of the form by which the user registers in the application. After registration, the user can use the login form, as shown in Fig. 6, which with the appropriate credentials allows the user to enter the system. Also, Fig. 7 shows the prototype of the main menu through which the user can access the different functions of the system.

- Sprint 2: In this Sprint, the implementation of the RFID tag reading module within the system was carried out. By means of this implementation, the RFID tags will be read and identified in order to unblock or block the electric fluid that allows the ignition and operation of the vehicle's engine. In Fig. 8 the system allows the user to appreciate which is the state (On - Off) in which the vehicle is.

- Sprint 3: In this Sprint, the implementation of the GPS module was carried out, which allows the location of the vehicle. In this sense, as shown in Fig. 9, this module provides the necessary information so that the system can graphically display the location of the
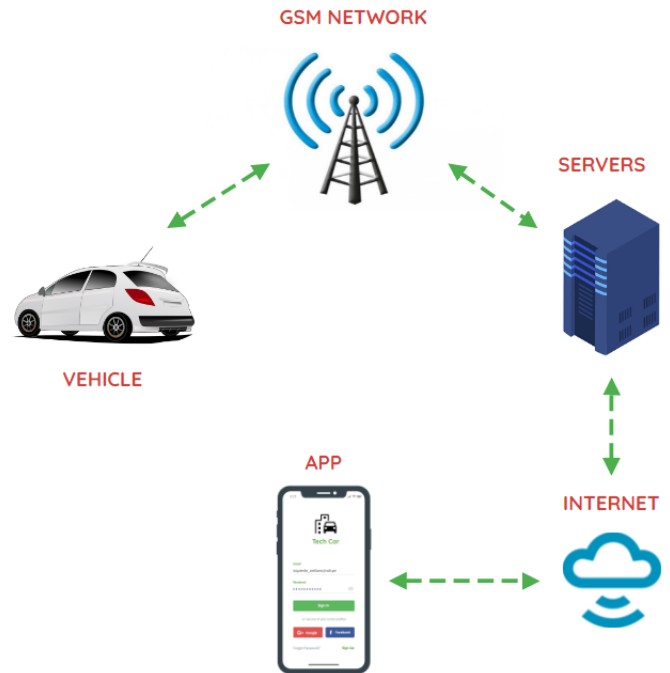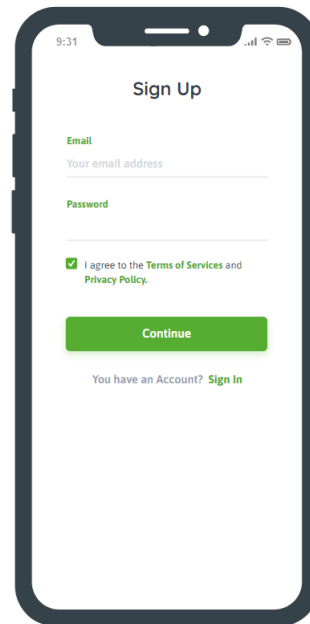

Fig. 5. Registration Prototype.

vehicle in real time, so that the user can know exactly where to locate the vehicle, since it has the coordinates of its location.

- Sprint 4: In this Sprint the implementation and connection of the video camera module is performed, as shown in Fig. 10 it allows the user to visualize the people inside the vehicle in real time. In addition, the options to allow and deny the use of the vehicle
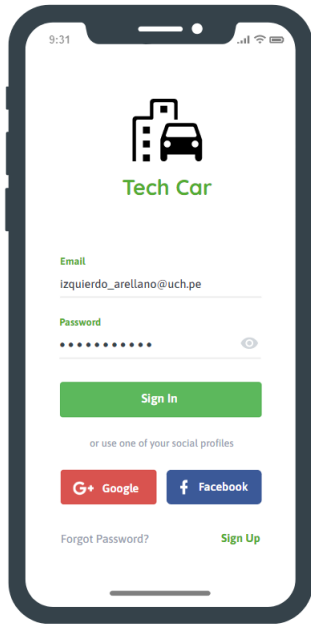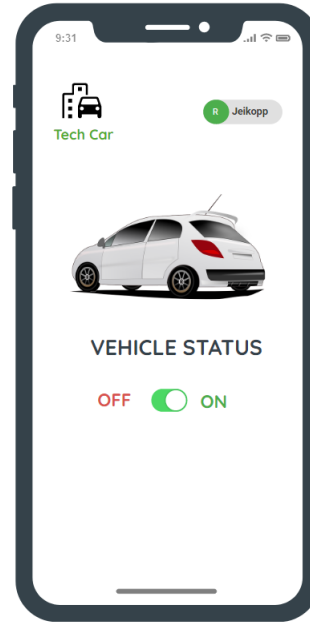
Fig. 6. Login Prototype.
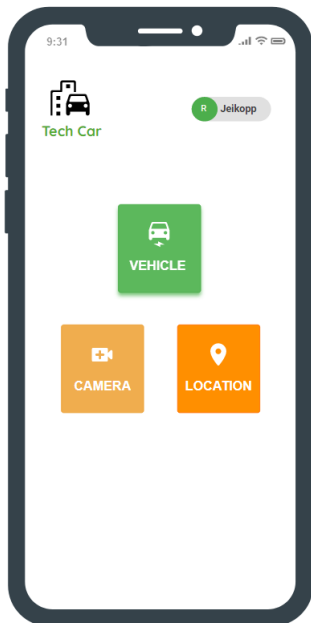

Fig. 8. Vehicle Condition Prototype.

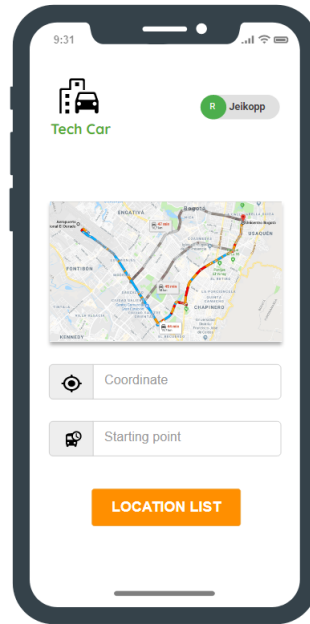Fig. 7. Prototype of the Main Menu.

Fig. 9. Vehicle Location Prototype.

according to the user's criteria were implemented in this sprint.

IV. RESULTS

In this section, the analysis of each of the results obtained after the development of each of the Sprints, which are part of the functional structure of this research project, was carried out.

A. System Analysis

Among the results obtained with the development of this research project, we find the flowchart, which is a guide that allows us to know which are the actions taken by the project in various situations.

In this sense, Fig. 11 shows that the system is activated after the vehicle ignition action is performed, then the identification of the RFID tag is performed, which when not identified launches a forced ignition alert. Then, the location of the vehicle is visualized through the use of the GPS device that has
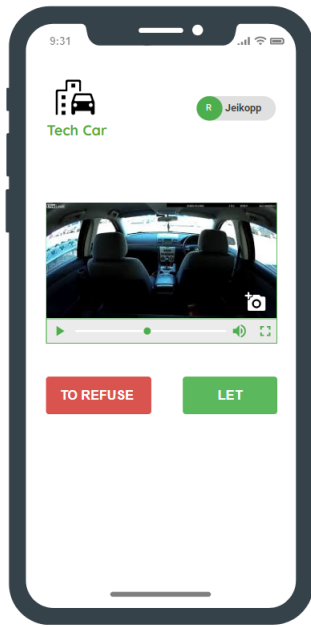
Fig. 10. Prototype of the Visualization of People Inside the Vehicle.

been implemented. In addition, it starts with the transmission of video images, which can be viewed by the user in the application. Finally, there is the option to authorize the user, in case the use of the vehicle is necessary. If the user is not authorized, the vehicle operation is blocked, which is confirmed with a notification.

B. Anti-theft System

1) Notification of Ignition Attempt: As part of the implemented system, RFID tags are used to detect when someone tries to start the vehicle in a forced way. Thus, when someone makes an attempt to start the vehicle without the RFID tag, the system immediately detects the non-existence of the RFID tag reading so it launches a notification which will be displayed on the vehicle owner's computer.

Therefore, after the non-existence of the tag has been detected at the time of the vehicle ignition attempt, an alert is launched in Fig. 12 shows the notification that is displayed by the user from the start menu of the application, which provides access to the functions of GPS location or access to the vehicle's camera module.

2) Notification of Unauthorized Ignition: Now, when the vehicle is started by force or unauthorized by a person who does not have the RFID tag, the system detects that the engine is running and sends an alert to the user in Fig.13 shows the respective notification from the start menu giving the user access to the GPS and Camera module options.

3) Vehicle Locking: When the vehicle has been forcibly started, the user can, as shown in Fig. 14, access the vehicle's camera module and view the real-time video feed from the vehicle's cabin. In addition, it is possible to visualize the person who started the vehicle, so the user has access to the options to allow the use of the vehicle in the case of an authorized person or to block the use of the vehicle.
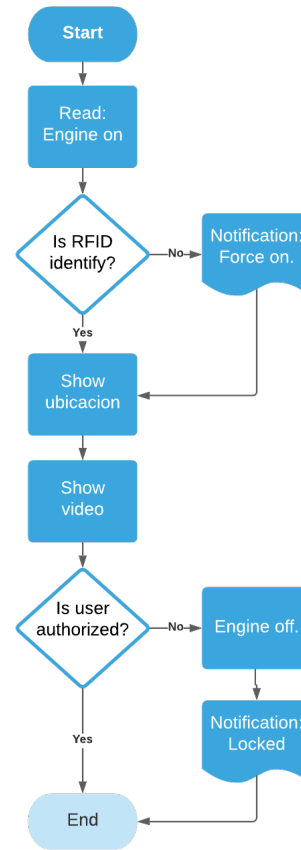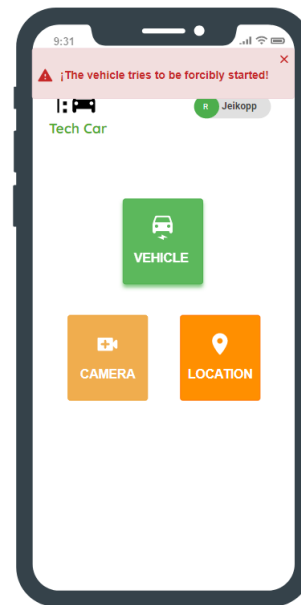

Fig. 11. System Flow Diagram.

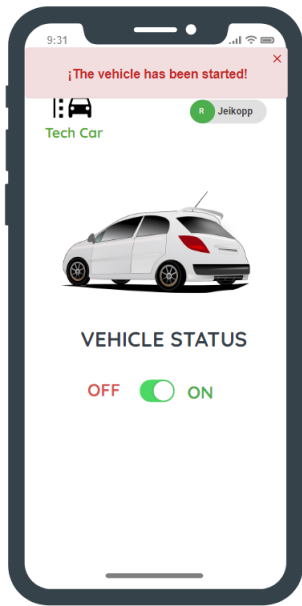Fig. 12. Alert from the Main Menu.

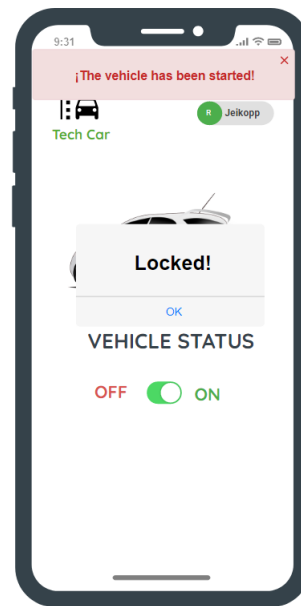Fig. 13. Vehicle Status Alert.
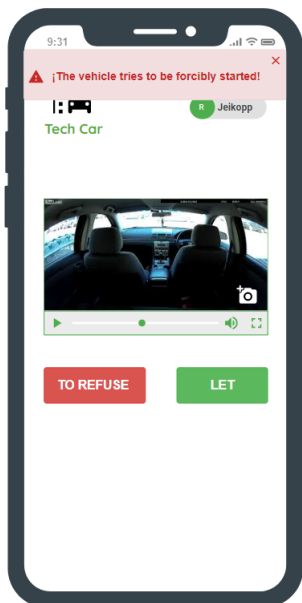

Fig. 15. Locking of the Vehicle.

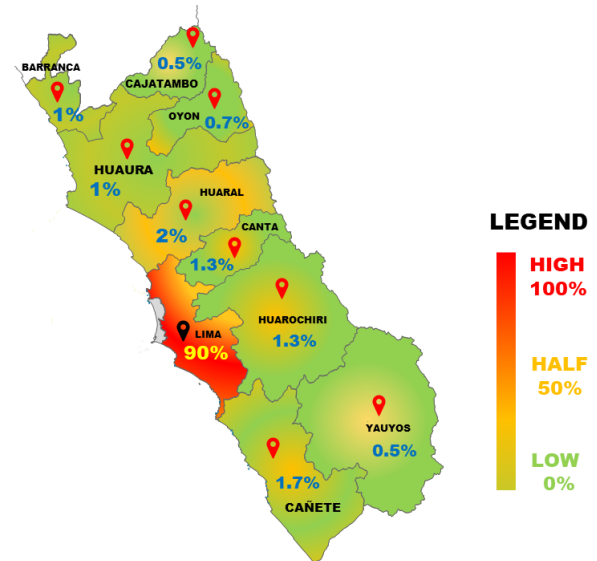Fig. 14. Alert from the Camera Module.

Fig. 16. Heat Map of the Crime Rate in the Department of Lima - Peru.

In fact, when the user determines that the person inside the vehicle is not authorized, he has an option in the system that allows him to block the vehicle. Thus, Fig. 15 shows that when the user blocks the vehicle correctly, he will be notified with a message on the device.

C. Analysis of Robberies in Lima

This research was developed in response to the problem of vehicle theft in the department of Lima, Peru. As shown in Fig. 16, the department of Lima has a vehicle theft rate of no more than 3% in its different provinces; however, the department of Metropolitan Lima has the highest rate, reaching 90%.

The purpose of this research project is to progressively reduce the rate of vehicle theft in the department of Metropolitan Lima. In Fig. 17 we can see that this rate is reduced over time because users have access to the location of their vehicle in real time, the means to visualize who is inside their vehicle, an RFID tag identification system, and the possibility of remotely blocking the vehicle through the IoT application.

This project, being implemented with IoT, allows the user to access the information of those devices with which it has, in addition, it offers the option of interacting with them by giving remote indications, which greatly facilitates the remote control of the vehicle.
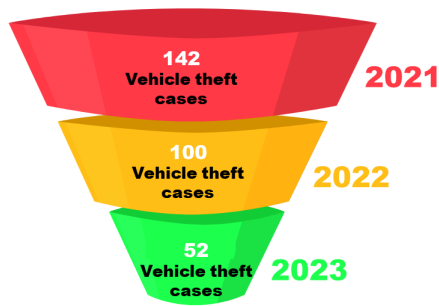
Fig. 17. Crime Projection in Lima - Peru.

V. Discussion

The present research has certain differences in comparison with other research papers dealing with the same technologies.

In fact, he took the trouble to [6] as a reference to the management of the information provided by the sensors to the Arduino device and then transmitted to a mobile application. On the other hand, in our research project the same principle was used to detect the information from the different devices that are connected to the Arduino and to be able to perform actions with them remotely.

In this regard, in comparison with the system developed by [7] which uses the vehicle's coordinates to be displayed by means of text messages on the owner's mobile device, in our system we use these coordinates through an API which allows the visualization by means of a map, allowing a better visualization of the vehicle's location by the user.

Likewise, in the work developed by [1] the system displays the location of the vehicle in the same way with the possibility of sending messages as a response and that these provoke an action in the system. However, in our system the same actions are shown with the difference that they are not a text message, but are commands that are executed after triggering them through the interface which is safer and easier for the user because it can not always have in mind the commands to send them by a text message. It is suggested to carry out research on the topic of RFID implant application such as [19] indicates that this technology can be used for the identification and subsequent operation of devices, thus avoiding the use of tags that can be easily stolen or lost by the user. It is also recommended to study the work of [20] which explains in detail how RFID implant technology works and the different applications that can be performed with it. Therefore, it is recommended to involve a Systems Engineer, an Electronic Engineer, an Automotive Technician and a General Practitioner, in order to carry out a multidisciplinary research.

VI. Conclusion and Future Work

In conclusion, this research allows, through the fusion of different technologies together with the IoT, the reduction of crime levels in vehicle theft, which favors all those who need an innovative system that offers various options in the management of this type of situations. The agile methodology with its scrum framework, allowed to have a more holistic outlook for the design of the prototypes. As a future stage to

be developed within our system, it is suggested to develop a history of the locations where the vehicle has been the victim of attacks to obtain data from the places with the highest rate of vehicle theft attacks. There were certain limitations to the analysis that were beyond the scope of systems engineering. In this sense, it is suggested to carry out research in an interdisciplinary, multidisciplinary way, that is, with sociologists, electronic engineers, among others.

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