Design and Implementation of a system based on Augmented Reality to support ITS equipment maintenance processes focused on Variable Messaging Panels.

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Abastract - In this document, the research and development demonstration of a prototype of a mobile application using augmented reality is shown, to facilitate the maintenance activities of the variable messaging panels that are distributed in the country. And this reduces the time and cost required to perform the maintenance activities of the panels. The document contains the most relevant and general concepts that were used for the final construction of the prototype.

Keywords: Variable messaging panel, augmented reality, maintenance.

I. INTRODUCTION

This research paper shows the process that was carried out to develop a mobile application or prototype to support the maintenance process to the Variable Messaging Panels that are installed in Colombia. Information is presented on how many variable messaging panels are installed in Colombia, more specifically in Medellin and what is the brand that is currently being used. For this purpose, the current requirements of the Colombian Ministry of Transport for the maintenance of ITS equipment and the periodicity with which it should be performed were considered. [1] To provide a solution to the maintenance requirements to be performed to the VMS, a research process was carried out to know the technical conditions of the panels and the emerging technologies that are currently being used to solve maintenance problems of tools and infrastructure. [2]. After all the research continued developing the prototype considering the subsystems and the appropriate architecture to solve the problem. Finally, it is presented in the document the results obtained and the conclusions that were found for the research paper.

II. PROBLEM STATEMENT

Nowadays, technology companies must acquire and innovate in the use of maintenance tools; these elements that are available must be constantly monitored and managed so that the processes that rely on technology in some way or another are efficient and are operating properly for the required time according to the industry.
There are several technologies that are directly related to the area of intelligent transportation systems, an area of great importance for the generation of value-added services for travelers, citizens and people who make use of the transport infrastructure, in this sense the senses that are deployed in the field to perform measurements or any mobility event that you want to determine requires that the devices are properly calibrated and functioning properly.

For no one is a secret the progress that has had the technology and for this case enters one in particular, which is very important emerging called Augmented Reality, this brings some features that allow to strengthen the maintenance processes of the equipment. Currently most of the ITS equipment that are deployed in Colombia are not manufactured in the country, and the training of people who perform maintenance work is low.

For all the above, in this degree work will take advantage of augmented reality to generate monitoring and maintenance processes and thus improve the quality, efficiency and agility of the possible problems that may occur along a road. For this case, initially this thesis proposes to do this for the ITS element called variable messaging panel, which aims to display messages to citizens related to traffic and traffic conditions of the roads or important information that should be known.

III. JUSTIFICATION

Day after day the human being is delegating part of their responsibilities to current technologies and emerging technologies, this is evidenced by the growing number of electronic devices that surround us and perform tasks that previously performed by a person, product that companies took advantage of these technologies, to deploy them in multiple fields: medicine, transportation, security, information and so on.

However, this leads to multiple factors to consider once the technology is in place, a large part of these devices, such as devices for ITS require constant maintenance work to ensure its functionality, with each device that is purchased, it requires a medium- or long-term maintenance, which usually becomes repetitive in the short term.

This issue is generally managed by public administrations, which seek devices such as variable messaging panels, to mitigate situations such as accidents and thus avoid increasing the number

of deaths in Colombia, considering the emphasis that the National Road Safety Agency has on this issue. [3]

Through ITS technology deployments, they have the disadvantage of opex and/or maintenance processes that are specialized tasks, particularly for each device, it is not a general knowledge and requires a person who is a specialist in the device or technology in question and the brand.

As the number of devices is increasing, so is the need to maintain all these new devices for optimal performance. Unfortunately, the knowledge necessary to train people in these latest technologies is not available, there is no such thing as a "VMS maintenance course", there are no universities, study centers or careers for ITS elements or maintenance of these.

Therefore, people learn directly from suppliers when they offer that option, but those technology providers that do not offer as such a clear documentation and in a language understandable by the technician or training, hinder the maintenance of the devices, the result of this situation is to have fewer technicians with the necessary skills to perform this work.

This research project seeks to reduce the time and support in maintenance activities to variable messaging panels that must currently develop contractors and not rely on the expertise of personnel responsible for repairs, each brand, taking into account the requests 3.1.1. made by the Ministry of Transport in the Technical Annex of the Project for the Adoption of Functional and Technical Requirements for Variable Message Panels for the Country.

For them we will make use of other emerging technologies that can support the maintenance work and that currently has on the market, the utilities that have been found in Augmented Reality for Industry 4.0 opens the possibility of taking advantage of this technology for our goal.

By using protocols, storage in different media and real time information it is possible to obtain data regarding certain objects such as, for example, the stock number, characteristics of the object to be monitored, parameters, temperatures, the place where it should be taken for storage, information regarding a package, among others.

This makes it easier to perform tasks, considering that in addition to allowing quick and easy access to information, it also facilitates the way in which information is displayed. [4]

IV. FRAME OF REFERENCE

In this numeral the different concepts, theories and fundamental laws for the development of the research project will be related. For this reason, the main ideas that refer to the subject will be described.

A. CONCEPTUAL FRAMEWORK

The conceptual framework refers to the main definitions of the concepts that will be discussed throughout the project. To give a better understanding of these and in turn give clarity to all the points discussed.

1. INTELLIGENT TRANSPORT SYSTEMS

Intelligent transportation systems, (ITS), are growing modern systems that apply advanced computing, telecommunications, and multiple technologies to provide information to multiple elements of public transportation, such as traffic networks and vehicles, to reduce vehicle congestion, vehicle emissions, energy expended, travel times, and generally make the public transportation sector more productive. [5]

2. EMERGING TECHNOLOGIES

Emerging technologies are innovations in developments that, as its own name says, in the future will change the way of living of human beings, providing greater ease at the time of performing their daily activities. Emerging technologies are shaping our current society, our habits, the way we interact and communicate, the way companies manage and generate their products, the way of education. These are technologies that move humanity evolving the whole current culture. [6]

3. INTERNET OF THINGS

It is the connection of the objects that surround us to an interconnected network, using a basic intelligence integrated to an operating system using commonly used protocols integrated into the device, which will make use of the network to send or receive data and perform everyday functions through routines or by sending information to other systems that will process such data. The Internet of Things is related as a true evolution of what is known as the Internet and adding a much wider interconnectivity, has a better perception of information and more complete intelligent services. [7]

4. INFRASTRUCTURE

Infrastructure refers to the devices that enable the transmission of signals (lines, microwaves, satellites), and from this transport of communication protocols and routing devices. Also, as computing devices and programs that are involved in the interpretations of information such as operating systems and communication protocols that reach users, either by own access devices or shared devices in a computer center. [8]

5. MONITORING

Monitoring of systems involves the collection of frequent data to measure progress towards meeting objectives. Monitoring is used to keep track of performance over time and is intended to support stakeholders in making decisions regarding the effectiveness and efficiency of resource use. [9]

6. MOBILE APPLICATION

Program created to work on mobile devices to facilitate the life of users to perform various functions or tasks.

The functions that a mobile application can have vary depending on the application itself, they can be used for simple functions such as making a calculation, giving time or date, a little more complex as organizing a schedule, tracking activities or visiting social networks and very complex as developing plans, using augmented reality sections to offer experiences or allow tracking and management of platforms in the cloud, all these are generally financed in various ways, there are applications that are acquired through a single payment and applications that are paid monthly, the latter do not necessarily require payment by the user who uses them, as often the application is monetized by displaying advertising, so it is the sponsor of the advertising that pays the application to allow it to display ads. [10]

7. MOBILE OPERATING SYSTEM

Mobile operating systems or mobile OS are those that control mobile devices whether tablets or smartphone cell phones, just like computers use operating systems such as Windows, Linux or Mac OS among others, it is taken into account that mobile operating systems are simpler and are mainly oriented to wireless connectivity, and multimedia formats for mobile, currently the two most used mobile i. operating systems are Android and IOS. [11]

8. VARIABLE MESSAGE BOARDS

Variable Messaging Panels (VMS) are those devices that allow traffic control, these are used to provide roadway information to motorists. The information can be displayed in real time and can also be ii. controlled either from a remote center or locally on site. VMS are designed to affect driver behavior, to keep drivers informed and thus improve the flow of traffic and roadway operations: [12]

- Travel times between known destinations
- Congestion conditions along a freeway corridor
- Construction Notices
- Notice of special events and instructions
- Maintenance operations schedule
- Incident Notification

B. THEORETICAL FRAMEWORK

Theoretical support is developed to explain the development of this research project. In the same way the first approximation to the technology with which the solution to the mentioned problem will be given is shown.

1. MAINTENANCE

The maintenance are all those activities that must be developed in a logical order, aims to preserve in good condition the safe, efficient and economical operation of devices, tools and other physical properties that are used for any purpose either in business, for study or to perform any activity.

Over time the development of technologies and industrial facilities, every day becomes more difficult and automated with large production lines, and if the industry is suspended in the use of the tools can present large economic losses. Maintenance is important because of the need that organizations have nowadays 24/7 to be in operation to users providing services, and when failures occur it is necessary to restore services quickly, thus reducing impact times and production losses. [13]

2. PREVENTIVE MAINTENANCE

Preventive maintenance is the detection of faults before they become critical, without altering the normal operation of the device. In this way we try to reduce the number of corrective interventions through the application of a system where inspection routines can be executed and renewal of elements that are in poor condition. This maintenance is planned over time.

3. CORRECTIVE MAINTENANCE

"Corrective maintenance does not require systematic planning and is put into practice when the equipment presents a failure, this means that when maintenance is reduced to the repair of equipment or machinery producing a damage in the manufacturing process and decreasing the services to be performed." [14]

4. AUGMENTED REALITY

Augmented reality is one of the emerging technologies that is often used to define a vision through a technological mobile device, directly or indirectly, of a physical environment corresponding to the real world, the elements of reality are combined with virtual elements creating in this way to generate a mixed reality in real time. The main difference is the superimposition of virtual elements on images of the real world. [15]

C. LEGAL FRAMEWORK

The legal framework refers to the international and national standards that represent the variable messaging panels, giving compliance to internal development through policies, standards, legislation, and principles. The main standards that support and require the correct operation of variable messaging panels were identified.

1. LEGAL FRAMEWORK AND STANDARDIZATION

Within the international legal framework, there are a series of standards that provide minimum guidelines for the operation, maintenance, and infrastructure of Variable Messaging Panels.

- Standard 12966-1:2007: European standard that specifies the type of panel, it is defined in this standard that can be continuous or discontinuous variable messaging panels, the continuous ones contain fixed signs that were defined in the EN 12899 standard and the discontinuous ones are those that show different messages, the 12966 standard shows and specifies the visual and physical characteristics of the panels, including longevity of this, it also defines requirements and ways to test and verify them.
- EN 12767: Passive safety of supporting structures for road equipment.
- EN 12899: Fixed and vertical traffic signs - Part 1: Fixed signs.
- ISO 7000: Corresponds to the graphic symbols to be used in equipment - Indexes and synopses.
- CIE Standard No. S 004/E: Colours of illuminated signals
- ISO 14813-1 of 2015: Also called the reference model for ITS sector architectures.

Defines the scope of ITS services that can be deployed in a national territory, "the specific case for Variable Message Systems that are part of the ITS Traveler Information Domain".

- ISO 14813-5 of 2010: Also called Reference Model for ITS sector architectures40, it establishes the parameters on the architecture for ITS systems, it is used as a basis by SINITT to define the terms to be used in the documentation referring to architecture standards.
- IEC 60664-1 Standard: Insulation coordination of equipment in low voltage systems (networks).
- CEN/TS 16157-4: Intelligent Transport Systems.

2. NATIONAL LEGAL FRAMEWORK

It is necessary to emphasize that the legal framework that regulates the operation of variable messaging panels in the country has basically two normative sources.

The first one, coming from the National Traffic Code, concretized in the Road Signage Manual and mandatory for the whole country, and the second one of contractual type,

generated in the regulations made by each entity when acquiring the equipment. [1]

- National Land Traffic Code: LAW 769 OF 2002, contains the rules governing the entire Colombian territory and the regulation of the circulation of pedestrians, users, passengers, drivers, motorcyclists, cyclists, traffic agents and vehicles on all roads in the country.
- Resolution 1885 of 2015, is the resolution by which the "Manual of road signage - for ITS devices this in order to control traffic regulation on streets, highways in Colombia" is adopted. This resolution defines all the specifications of the signaling elements, including variable messaging panels.
- The contractual normative source, this source is too limited, as it is restricted to define the technical aspects corresponding to the equipment that is responsible for transmitting variable messages, however, it is responsible for regulating the types of messages, interoperability requirements, protocols and instructions for the design and transmission of variable messages. It is also important to talk about this regulation, considering that it is responsible for defining the legal mechanisms that are used to acquire and operate variable messaging panels in Colombia. [1]

V. VARIABLE MESSAGING PANELS

In this section, an analysis is made of the variable messaging panels and the services they provide, what are the technological features that manufacturers use, the parameters and methods of operation of the panels, the devices presented in this section are devices currently used and the information was taken directly from the manufacturers.

A. TECHNOLOGIES IN VARIABLE MESSAGING PANELS

At present there is a great diversity of technologies that somehow generate technological devices that can project messages to users, there are currently multiple varieties of companies that generate multiple panels of different technologies, such as discs, LEDs (diodes).

B. MANUFACTURERS

The External Works Index site was consulted to determine the main manufacturers and developers of VMS technologies and several were found, the following list shows 6 of them. [16]

-Altaroute: Designs and manufactures variable message signs with electromechanical rotating prism.

-Colas: Leading provider of intelligent visualization and control systems AND intelligent visualization systems (IDS).

-PWS Ireland: Specialises in signage for roads, car parks, schools, hospitals, leisure centers and industrial complexes. Road markings include interior illuminated signs, pedestrian bollards, and road markings.

-Siemens Mobility, Traffic Solutions: Elektra, variable messaging signs (VMS) provide effective information displays as part of an integrated UTMC traffic management system.

-Swarco Traffic: Designs and manufactures traffic information systems, including interchangeable signs.

-Aesys: A pioneer in the LED and LCD-TFT display industry, it has been synonymous with excellence for over forty years.

C. GENERAL

Signs are used in the traffic areas of the roads to inform motorists about any conditions of problems related to traffic flow (flow, accidents, road works).

The environment is characterized by the occasional presence of dark oily particles dark oily particles due to vehicle emissions (truck and trailer exhaust pipes); more so, during winter due to the presence of salt transported and sprayed by trucks in transit and the site is subjected to low temperatures and high humidity levels. [17]

VMS are subjected to strong gusts of wind with pressures and back pressures generated by passing vehicles, inflicting both stresses and vibrations on the structures.

The CPU is connected to the central operating station (Host computer server) which has the task of transmitting messages concerning the feasibility conditions of the highway in real time, as well as receiving the operating status of the VMP: the modalities of message exchange (protocol) between Host and CPU of the panel are described in a paper.[17]

D. FEATURES

When the panel is switched on, in the absence of programmed messages, an illuminated dot (a group of pixels) appears at the bottom right of the display. From the Host, or from the laptop, it is possible to activate the display of a pictogram in the full-colour zone and of a message in the monochrome zone at any time. The message activation modes are illustrated in the specific manual. The panels can be programmed with a series of parameters which set the functions in standard and particular conditions: - Brightness level: the panel maintains the LED brightness at a fixed value. - Automatic brightness: the panel is equipped with a brightness sensor. [17]

E. VARIABLE MESSAGING PANELS IN CITIES IN COLOMBIA

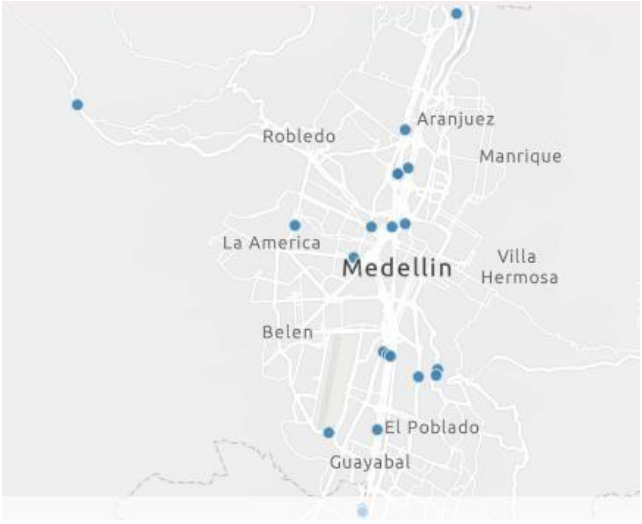


Figure 1Medellín Panel Map

https://geomedellin-medellin.opendata.arcgis.com/datasets/891a8c35fd6e417db6e3dfcc29 4dd782_8?geometry=-75.836%2C6.188%2C-75.373%2C6.307

In Colombia the number of variable messaging panels is smaller, and the vast majority are manufactured by Aesys, although there is no exact number visible to the public, we can take as a reference some cities that currently implemented these panels on their roads, Medellin is a good example of this.

Medellin, known as the capital of Antioquia, has 382 km2 compared to the 1,775 km² of Bogota. [18] Medellín has 22 panels on its roads, which transmit information to residents about the state of the roads, the days of peak and plate, and accidents accompanied by an image. For the inhabitants of the city, these have become one of the tools that bring much value as it offers relevant and important news that allows quick decisions regarding routes and which roads to use.

F. AESYS VARIABLE MESSAGING PANEL

Next, we will review and emphasize the Aesys brand panels, considering that it is the most used manufacturer in Colombia.

These panels have a series of controls and hardware that demand maintenance, as are the important parts of the panels is, first, the CCU which is the central control unit, this varies in its characteristics, but for this work will be used as an example the CCU has the following properties:

- 32 bit/16MHz Microprocessor
- 8mb flash memory, upgradeable
- 3.3v SmartMedia type memory slot
- Internal clock for the Ram memory with its own buffer
- Matrix type LCD, Black and White with 122 X 32 pixels
- Waterproof keypad with numbers, letters and functions
- 4 keys that allow you to select the direct options that are shown on the display
- 4 digital inputs
- serial ports
- Infrared data transmission
- Approximate weight 0,5 KG
- 24 Volt voltage with polarity fault protection

VI. MAINTENANCE METRICS

In this chapter we make an analysis and identification of the metrics that are used when assessing the status of a variable messaging panel and compared with the metrics that are currently used in augmented reality for the same scenario, before looking at the metrics is important to identify what are the indicators or parameters that are articulated to the maintenance approach that can be performed on VMS equipment that are in the field along the transport infrastructure.

A. RAMS PARAMETERS

It is important to know some terms that are defined in the maintenance and that due to their importance require their own sub-index, these are encapsulated in the RAMS parameters (MTTF, MDT, MTBF, MTTR).

RAMS stands for Reliability, Availability, Maintainability, Security and is designed as an analysis that allows forecasting time periods for the Reliability, Availability, Maintainability and Security of a system, product or facility.

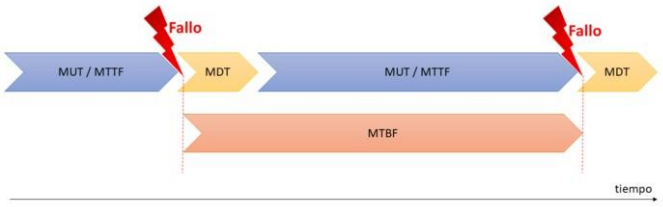


Figure 2Faulty system1

https://www.leedeo.es/_files/200000168-b0b72b1be8/700/parametros_RAM_1-4.PNG?ph=142b9359cb

In the graph of a system and a failure scenario, initially there is evidence of a system running smoothly on the timeline in blue color, after a time X which can be any time a failure occurs, in the graph the failure is seen as a red lightning bolt, a consequence of the failure is that the device is out of service, In the graph we see this time out in yellow, once the incident passes, again we have the system working normally and again is seen in blue, the system will operate normally until a failure occurs and repeat the chain of events (in many cases). [19]

B. INDICATORS

One of the most important elements in the variable messaging panels, in addition to the display that provides the information or the batteries that power the system, or the control panel that allows the configuration is the subsystem that allows communication with the control centers and to receive or send information in real time, this subsystem can send information about whether the device is on, where it is and that is showing, plus the ability to change the status or information displayed on the display, so it is important that communications have a high reliability.

1. Communication indicators

This indicator measures the availability of communications from the panel elements to the different devices that require communication or reception of data from the panel. This indicator does not consider failures due to elements supplied by third parties such as the power of the communication equipment.

Communications reliability is guaranteed to be equal to or greater than 98.5% per month (maximum 10.8 hours per month of communications downtime), calculated as follows:

$$\text{Porcentaje de cumplimiento:} \frac{\text{No. de horas de no disponibilidad del servicio}}{\text{No. de horas del mes evaluado}} x100$$

2. Indicators for operational readiness

This indicator measures the operational availability of the elements that make up the Variable Messaging Panel. Failures caused by third parties, such as power supply, are excluded

from this indicator as long as they last longer than the time required by the device's power backup or battery.

An availability of minimum 98.5% per month must be guaranteed (maximum 10.8 hours of unavailability will be allowed), calculated as follows. [20]

$$Porcentaje\ de\ incumplimiento: \frac{No.\ de\ horas\ \text{sin}\ funcionamiento}{No.\ de\ horas\ del\ mes\ evaluado} x100$$

3. Temperature indicators

There are three kinds of temperature ranges that have maximum and minimum ranges, in order to control the temperature of the panel. [21]

Class	Ambient temperature (C)	
	Minimum	Maximum
T1	-15	+60
T2	-25	+55
T3	-40	+40

4. Case protection indicators the protection of the boxes should be monitored, to know the level of protection against ingress. And it is monitored with three classes.

Class	Ingress protection level
P1	IP44
P2	IP54
P3	IP56

5. Electrical indicators

It is essential to have electrical indicators because they allow you to keep track of the voltage that is feeding the panel.

Test Sequence	Frequency value	Voltage value
1	Download	Download
2	Nominal	Nominal
3	Top	Top

Voltage value	Measure
Maximum voltage indicated by the protection device	Check that there is no incomplete or false partial display.

6. Impact indicators

It is carried out on the front panel of the module, using a 50 mm diameter steel ball with a mass of 0.51 kg which is dropped from a height of 1.3 m to produce an impact energy of 6.5 Nm.

The module is conditioned to a temperature of 20°c and then subjected to three simple impacts at the weakest point of the front panel.

As a result of the test, the front panel of the test module or parts thereof shall not show any damage, except for small indentations on the front surface; no cracks shall be present.

7. Vibration indicators

A shaking table is used; for large modules, it is a virtual point, where the spectrum of the reference signal is defined as the arithmetic measure of the ASD values of the signals measured at the control points.

Frequency range	10 Hz to 200 Hz
Levels of ASD	0.13g²/Hz (10 Hz to 50 Hz) 0.13g²/Hz (50 Hz to 200 Hz with a negative slope of 3 dB/octave) Overall acceleration RMS 1.2 g
Duration of conditioning	90 minutes in each of the axes
Reproducibility	Under

8. Corrosion indicators

This is done by visual inspection and also by operation, to identify the level of deterioration of the panel.

Measures	Visual inspection and function test
Module Status	Unpacked, closed and switched off
Duration	240 hours
Conditions	35°c ±2°, fog output neutral

9. Indicators through Virtual Reality

Through the use of virtual reality and a tool configured for it can receive data from the sensors attached to the variable messaging panel, as well as the sensors of some subsystems or hardware, such as the processor, memory, flash storage or rom, temperature sensors and you can use this data to identify possible hardware or software failures, adding to the application metrics and alarms which will launch notifications when something does not work properly, for the exercise of this degree project, there is no standard that defines which metrics would be applicable to the use of augmented reality for maintenance in VMS, because it has never addressed the issue of augmented reality in ITS for VMS.

VII. SYSTEM DESIGN

The present numeral is focused on showing the design of the subsystems that will compose the prototype for the maintenance of variable messaging panels using augmented reality.

The whole system is composed of a set of connected elements, which form each of the parts or subsystems, which will be responsible for performing the tasks for the proper functioning of this.

Variable messaging equipment is generally located in areas not easily accessible to the average person on foot, such as busy roadways and are located on metal structures at a specific height that facilitates visibility from a considerable distance and avoids blocking important aspects such as visibility by being away from the road and other vehicles, however, although they are far from exposure to vehicles or people, these panels can be seen in certain scenarios where failures are unavoidable.

Suppose there is a disconnection of the panel to the central, the central must send a technician who will be responsible for reviewing the device and provide corrective maintenance, if necessary, in a simple scenario we could consider the disconnection by connection failures device settings or reset, infrastructure failures such as damaged cables or failures in the power supply by natural or malicious damage.

In all cases the technician must rule out one by one all possible faults before finding the problem by investing a lot of time depending on the type of damage, unless there is a way to connect to the panel, as long as there is power in it, regardless of its connection to the infrastructure of the central, this problem is solved with a system that allows communication between the panel and a device that can diagnose it.

Initially we have a single element that is independent and performs its functions, in this case, the variable messaging panel, this contains its own subsystems and is connected to the central through its own communication protocols, these intelligent systems may contain tools such as a web server, communication protocols such as TCP/IP, SNMP protocol, remote and local interfaces for maintenance and configuration, also offer the ability to interact with other road equipment.

The starting point will then be this possibility of communication with other systems and communication protocols.

Taking into account the need, which is to do maintenance to the panel, initially it requires a subsystem to send information to the panel to know what is its current status, the first subsystem will then be responsible for sending information so that the technician can receive it, but where does this information come from?

For this there must be a subsystem that collects the information in the variable messaging panel and transfer it, this subsystem must allow the sending system to receive the information in real time and must also allow the information to be in a correct format, once the information is sent, there must be a subsystem in a device, preferably portable, that the technician will have at hand, for this project the mobile phone will be used, therefore the subsystem that receives the information must be in an application installed on the mobile device, this subsystem must communicate with another subsystem in turn, which will capture the information received on screen through virtual reality so that the technician does not lose the connection with their environment, the information received must be interpreted by the technician and thus can save time in their diagnostic work.

In theory the system is complete since what is sought, which is to send information from the panel and receive it on the mobile device is complete, however, we must protect the data that the panel sends, for this we will have an intermediate security subsystem, which will prevent anyone can access the data sent by the subsystem of the panel capture.

The diagram of the general system at a high level would be as follows:

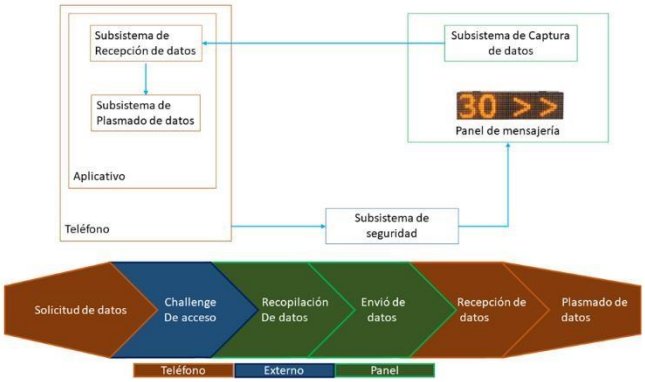


Figure 3High-level schematic of the augmented reality application and the interaction with the variable messaging panel. Own design

As the system must support the maintenance to be performed on the device, this can not only capture information received from the panel, as the user may not know what he sees on the screen due to lack of experience or could misinterpret the data received, therefore, the application must allow in addition to reading the panel values, must provide support to the technician on the most common maintenance routines of variable messaging panels, so it must have a subsystem that allows to capture these scenarios, could be through documentation, animations or videos, this subsystem will support the work of maintenance.

VIII. ARCHITECTURE DESIGN

This chapter will present the architecture design defined for the implementation of the prototype system based on augmented reality to support the maintenance processes of variable messaging panels, which refers to the objectives set out in the project.

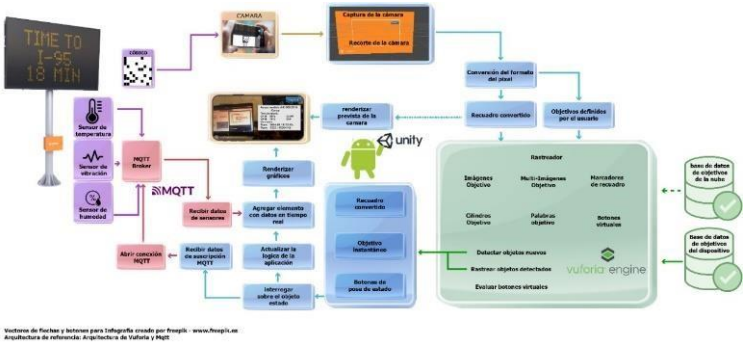


Fig 1General System Architecture, own elaboration

- The brown section shows the initial and final user interactions.
- The blue color defines the flow of the application for image acquisition, conversion and rendering.
- Green is composed by image crawling and comparison with the databases with Vuforia Cloud and Engine.
- Red color refers to the interaction that the application has with the messaging panel through MQTT.
- And purple are the elements that make up the messaging panel and interact with the application by sending data.

IX. PROTOTYPE IMPLEMENTATION

This section describes the implementation process that was carried out for the development of the mobile application that facilitates the maintenance process of the variable messaging panels using augmented reality.

Each of the alternatives that were taken are explained, analyzing the priorities they offer and the reasons why these options were chosen.

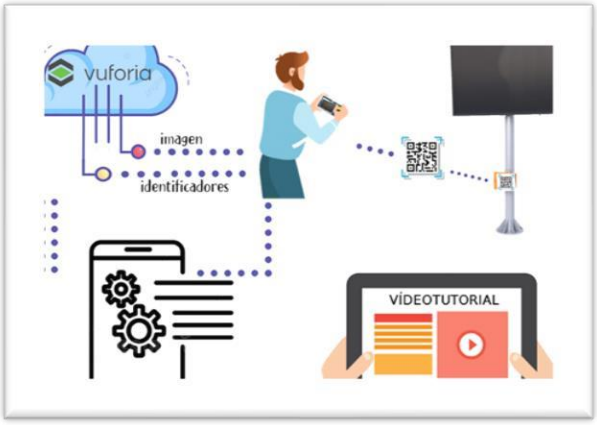


Figure 4General diagram of the system. Own elaboration

A. Technologies

We will describe all the hardware and software elements that were used for the construction of the prototype and mention which are the advantages offered by each of these technologies.

1. Vuforia

It is an SDK tool used for the construction of applications based on augmented reality, the applications that are developed using this tool use the screens of the devices as "magic lenses" where the real world is linked with the virtual elements, for this can be taken; images, texts, photographs, among others. [22]

- It has text recognition.
- It has image recognition (you can count on a previously taken image of a panel).
- It has robust tracking, as it has a fixed target that will not be so easily lost from sight even when the device is on the move.
- Fast target detection.
- Simultaneous detection and tracking of targets.
- Both on-premises and cloud databases

Figure 5Vuforia, own elaboration

2. Blender

Blender is an open-source software that serves to work with objects in 3d and you could say that internally includes several tools to work with. It contains tools for modeling, texturing, texture painting, particle editor, animation, rigging, sculpting. [23]

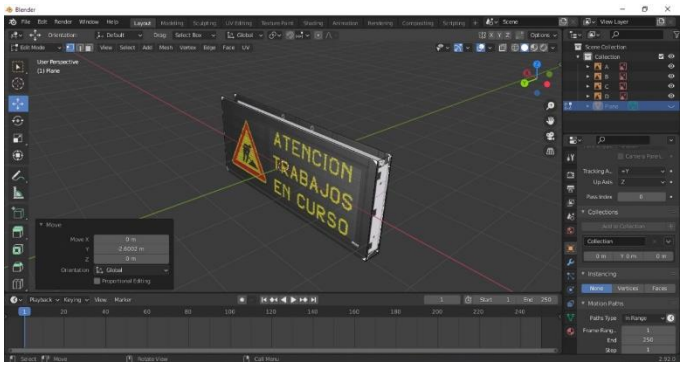


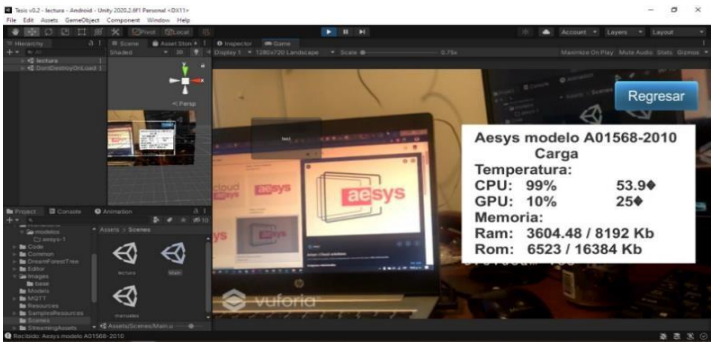
Figure 6Blender, own elaboration

Tool focused on modeling, curling and animated graphics in 2 and 3D, this tool allowed us to generate animated models of the variable messaging panels that would later be imported into Unity to be played in the application.

3. Unity

This program is very versatile and offers great features to create video games, this makes it very popular because it allows you to do a little of many things, its fame has it because its engine is multiplatform, so it allows you to export video games to computers, mobile devices with Android or iOS, and the different video consoles market. In addition, it is possible to program in different languages, among which this C# Unity has:

- Software Documentation
- Supports export to various platforms
- Has a community of users



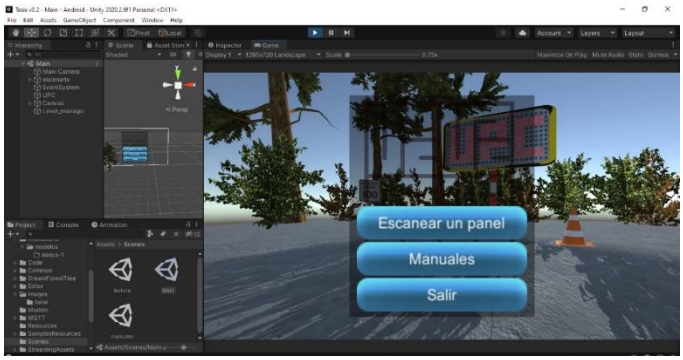


Figure 7Unity, own elaboration

4. Gradle

It is a tool that allows you to download the libraries that are needed. It is a tool that allows the automation of open-source compilation, which is focused on flexibility and performance. It is also the official build system for Android and supports a variety of technologies and languages. [24]

5. MQTT

MQTT (Message Queue Telemetry Transport) is a Client/Server message transport protocol based on publications and subscriptions to so-called "topics". Each time a message is published it will be received by all other devices subscribed to a topic of the protocol. ("#ESP32 - #MQTT (Introduction)")

The MQTT protocol runs over TCP/IP or other network protocols with bidirectional support and no data loss. ("EL") Its main features are:

- "Use of broadcast messages for application-independent data subscription and publication." ("EL")
- "Transparent, flow-optimized message transport that reduces network traffic." ("EL")
- It defines three qualities of service:
- "At most once" is basically the TCP protocol, but with message loss. This level could be used, for example, for sensing applications, where the loss of a reading is not critical because, sooner or later, we will get another one.
- "At least one", where the arrival of the messages is assured, but considering duplicities.
- "Exactly once", where the arrival of messages is assured exactly once. This level can be used, for example, with payment systems where duplicate or lost messages are more critical and could result in incorrect charges.
- It has a notification mechanism for unexpected disconnections.

B. Programming languages

They are formal languages that offer people, specifically those who develop programming activities. The ability to write a set of instructions, actions, orders through algorithms in order to control the physical or logical behavior of a system. In this section we mention the programming languages that were taken into account for the development of the prototype based on augmented reality. [25]

1. C#

It is a programming language designed by Microsoft®. This was It is a programming language designed by Microsoft®. It was standardized by ECMA and ISO two of the most important organizations when creating standards for services and products, this is an object-oriented programming language. This programming language was selected because it is compatible with Unity.

2. JavaScript

It does sensor simulation through scripting, JavaScript is a lightweight, interpreted, or just-in-time compiled programming language with first-class functions.

It is also known as a scripting language for web pages, and in some cases is used in environments other than the browser, such as Node.js and Apache CouchDB. It is a prototype-based, multi-paradigm, dynamic, object-oriented, imperative and declarative programming language. [26]

X. TESTS AND RESULTS

This section will show the process of the tests that were carried out and their results.
As a first step, Mosquitto Eclipse® was installed, which is an open-source messaging agent, available for versions 5.0, 3.1.1 and 3.1 of the MQTT protocol. Mosquito is very light and is suitable for use in all devices from computers to robust servers.

libeay32.dll	1,2 MB	Archivo DLL
mosquitto-1.4.9-install-win32.exe	204 KB	Ejecutable
msvcr120.dll	948 KB	Archivo DLL
pthreadVC2.dll	55 KB	Archivo DLL
ssleay32.dll	267 KB	Archivo DLL
Win32OpenSSL-1_1_0.exe	29,2 MB	Ejecutable

Figure 8Mosquitto8, own elaboration

For the installation process it was necessary to perform some extra steps such as; install Win32 Open SSL for Windows®, in its latest version and make sure that it saves the DLLs that Mosquitto will need in its own installation directory in BIN and not in the Windows System32 DLL directory, for this, in the installation of Win32 Open SSL, after choosing the installation path, select the checkBox with the option "The OpenSSL binaries (/bin) directory and it will be installed correctly.

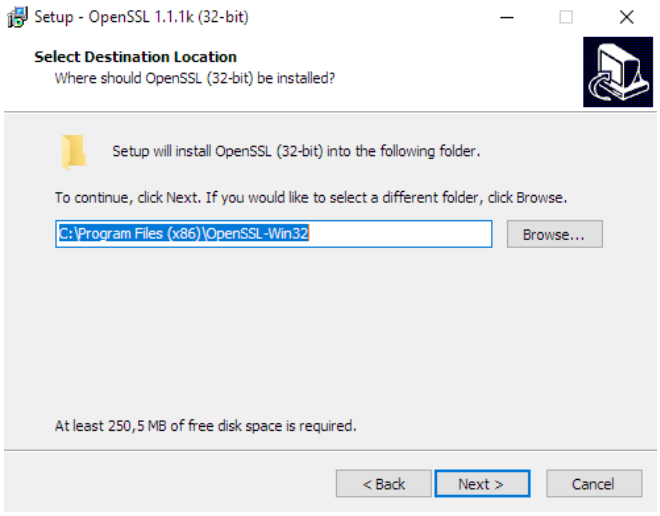


Figure 9Mosquitto9, own elaboration

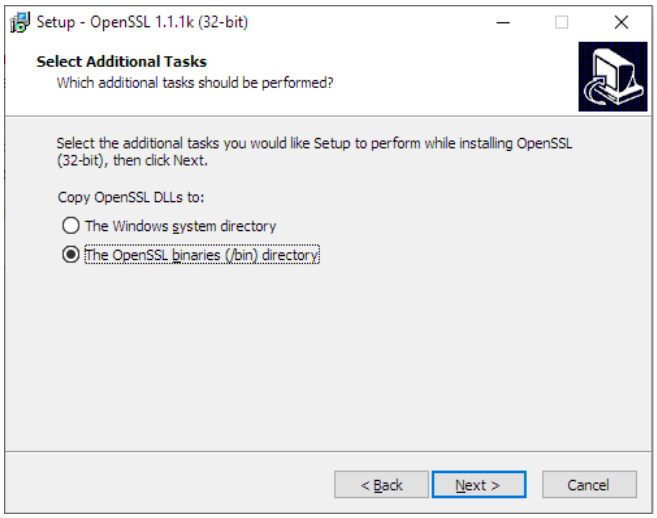


Figure 10Mosquitto Installation, own elaboration

Dispositivo	Lenovo	Iphone 7
marca	Vibe k5	Apple
pantalla	IPS 5 pulgadas	IPS 4,7 pulgadas
resolución	HD 1280 x 720 píx	1.334 x 750 pixeles
procesador	Qualcomm MSM8	A10 Fusion de 64 bits, coprocesador de movimiento M10
GPU	Adreno 405	Hexa-core
Ram	2 GB	2 GB
Rom	16 GB	128 GB
Camara	13 MP + 5MP	12 MP + 7MP

Pruebas de movimiento

	10 iteraciones	1,5 mts distancia	500ms entre dato		
	movimiento cada	distancia de movilier	% datos recibidos	datos perdidos	fallo de app
movV1	5 seg	aprox 5 a 10 cm	97,40%	~3%	10,00%
	10 iteraciones	1,5 mts distancia	500ms entre dato		
	movimiento cada	distancia de movilier	datos recibidos	datos perdidos	fallo de app
movV2	3 seg	aprox 5 a 10 cm	93,90%	~6%	0,00%
	10 iteraciones	1,5 mts distancia	500ms entre dato		
	movimiento cada	distancia de movilier	datos recibidos	datos perdidos	fallo de app
movV3	1 seg	aprox 5 a 10 cm	85,20%	~15%	0,00%
	10 iteraciones	1,5 mts distancia	500ms entre dato		
	Distancia de captura	distancia de movilier	datos recibidos	datos perdidos	fallo de app
movA1	5 seg	aprox 5 a 10 cm	98,00%	~2%	0,00%
	10 iteraciones	1,5 mts distancia	500ms entre dato		
	Distancia de captura	distancia de movilier	datos recibidos	datos perdidos	fallo de app
movA2	3 seg	aprox 5 a 10 cm	95,20%	~5%	10,00%
	10 iteraciones	1,5 mts distancia	500ms entre dato		
	Distancia de captura	distancia de movilier	datos recibidos	datos perdidos	fallo de app
movA3	1 seg	aprox 5 a 10 cm	90,80%	~9%	10,00%

Pruebas de lectura a distancia

	camara 7Mp				
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec1	variable corta y media	73,33%	86%	14%	3%
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec2	variable corta y media	76,67%	85%	15%	0%
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec3	variable corta y media	77%	85%	15%	0%
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec4	Corta - 1mt	97%	85%	15%	0%
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec5	Corta - 2 mts	93%	86%	14%	3%
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec6	Corta - 3 mts	93%	84%	16%	7%
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec7	media - 4mt	90%	85%	15%	0%
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec8	media - 5 mts	87%	87%	13%	3%
	30 iteraciones	10 datos	500ms entre dato		
	Distancia de captura	porcentaje de captura a la primer	datos recibidos	datos perdidos	fallo de app
Ejec9	media - 6 mts	77%	85%	15%	0%

XI. CONCLUSIONS

-The main objective of this research work was to provide an application to speed up the maintenance activities of variable messaging panels, using emerging technologies such as augmented reality and that it was not necessary a greater knowledge and expertise by the technicians responsible for performing maintenance activities of the panels.

-In this way, the functional prototype was developed, which was called mobile application for maintenance of variable messaging panels, which sought was that by taking pictures of the AIVMS code which has a panel, the current analysis of the panel was made and in

turn show what would be the most appropriate maintenance activity to be done and also consult the interactive maintenance manuals.

-With all this it can be concluded that from the research work which was the main functions of the application, of the subsystems that were proposed and will be mentioned below.

-As a first step, it is very helpful for technicians who do not have many years of experience performing maintenance to variable messaging panels, through interactive animations and user manuals which have the application developed in the research work.

-Similarly, the times in which the maintenance activities required by the Ministry of Transport are carried out had a considerable decrease and the two types of maintenance requested by the same entity as well as the periodicity indicated by the same governmental entity are met.

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