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Article

Design of digital ignition control of compact vehicle engine using fingerprint

Diseño de control digital de encendido de motor de vehículo compacto mediante huella digital

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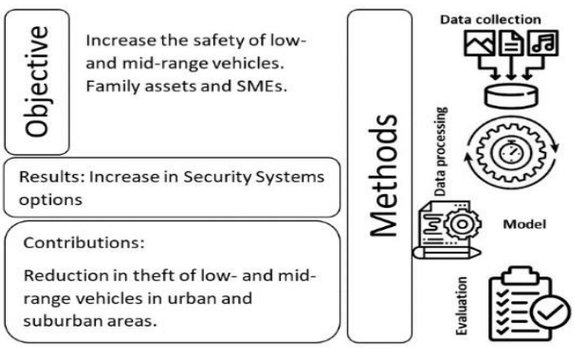
Abstract

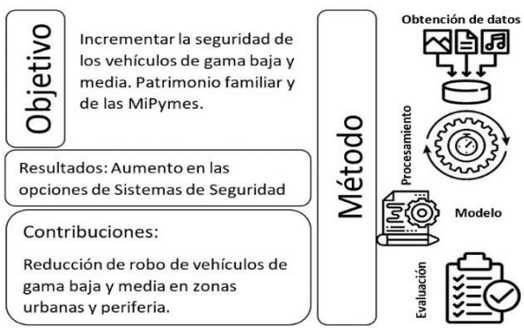
Over the past decade, vehicle thefts in México have increased, mainly due to the lack of accessible and effective security systems. Most engine ignition control systems are available only in high-end cars, while more than 90% of the population uses mid-range or low-end compact vehicles that lack this technology. To address this need, the design of a security system that uses a fingerprint reader, together with a commercial control card and communication modules, to offer an intuitive method of engine ignition control in low-end vehicles is proposed. This approach seeks to improve automotive security at a reasonable cost.



System, Automotive Engine, Fingerprint

Resumen

En la última década, los robos de vehículos en México han aumentado, principalmente debido a la falta de sistemas de seguridad accesibles y efectivos. La mayoría de los sistemas de control de encendido del motor están disponibles solo en autos de gama alta, mientras que más del 90% de la población utiliza vehículos compactos de gama media o baja que carecen de esta tecnología. Para abordar esta necesidad, se propone el diseño de un sistema de seguridad que utilice un lector de huella digital, junto con una tarjeta de control comercial y módulos de comunicación, para ofrecer un método intuitivo de control de encendido del motor en vehículos de gama baja. Este enfoque busca mejorar la seguridad automotriz a un costo razonable.



Sistema, Motor Automotriz, Huella Digital

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Introduction

Today's cars are equipped with many computers, as mentioned by (Mohammad, et. al. 2023), which allow the development and execution of various systems, such as the autonomous system, to assist the driver and improve the driving experience, said system is identified by its acronym in English DAS (Driving Assistance System), Engine ignition by means of fingerprint identification, previously registered in a system, Autonomous Driving, among other systems. Something in common with these systems is that they all incorporate different technologies for their development, but most conventional cars are not equipped with these systems, and the option to be able to equip them is very expensive.

The ECU (Electronic Control Unit) is responsible for controlling all the electronic systems on board a car. The market regularly identifies these cars as being at least ten years old, as explained by (Autopresta, 2024) due to the issue of depreciation to the current date (2023).

They are not exactly considered obsolete, but rather, non-current cars, that is, they do not have recent digital technology. The general classification of vehicles is known as low-end (compact size between 3 and 3.7 meters, cost between $170,000 and $280,000, type A, four cylinders, 1,000 to 1,400 cm3, with or without electrical functions such as raising and lowering windows), medium and high, in the USA (United States of America) the classification is done by size, specifically in Mexico the AMIA (Mexican Association of the Automotive Industry) classifies them in: Subcompact, Compact, Luxury Cars and Sports, in the same way there are various electronic devices such as development cards of the Arduino platform, including the following modules, as mentioned (Zein, et. al., 2018) GPS modules, LCD (Liquid Crystal Display), including audible and visual alarms, as well as specific communication modules such as Bluetooth or others for specific purposes such as Driving Motor, Steering Motor and LM239 H-Bridge.

In the development of vehicle anti-theft and access control systems (R. Thanuj, et. al. 2023), programming languages such as C language, present in the Arduino integrated development environment (IDE), are used or involved.

The code to enable the enable/disable functionalities of ports / sensors / actuators or other system operations, which involves the application and execution of instructions within a microcontroller, for projects that require a friendly and versatile development environment in their programming, allowing developers to write, compile and upload code easily.

In addition, Arduino offers a wide range of libraries and resources that facilitate the programming of electronic devices and the integration of different components into a complete system.

Specifically for the topic of biometric authentication (Bharania, P. J. et al 2023), it mentions that it is an excellent system, combined with the use of ZigBee communication technology, which is a wireless communication standard designed for low-power and short-range applications.

It is based on the IEEE 802.15.4 standard and is mainly used in sensor networks and devices that require efficient and reliable communication. In its system it describes the improvement in the access and operation of trains, which prevents unauthorized persons from turning them on.

An anti-theft security system for vehicles that uses biometric technology (Brijet, Z et al 2017), specifically a fingerprint sensor, in combination with an Arduino UNO board to control the ignition of the engine. This system is designed to ensure that only authorized persons can start the vehicle, which significantly improves security and reduces the risk of theft, the operation of the system is based on a R305 fingerprint module that is connected to an Arduino UNO board. When a user tries to start the vehicle, he or she must scan his or her fingerprint.

The fingerprint sensor verifies the user's identity by comparing the scanned fingerprint with the fingerprints previously stored in the system.

If the fingerprint matches the preloaded data, the system activates a relay that supplies voltage to the ignition system, allowing the engine to start. In case the fingerprint does not match, the relay is not activated and the engine is started.

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Remains off, preventing unauthorized access. Advantages of the System: First, it is considered more secure than other traditional security methods, as fingerprints are unique to each individual, making it difficult to duplicate or bypass the system. In addition, the system is low-cost, highly efficient and compact, making it accessible and practical for implementation in a wide range of vehicles.(Juwariyah, Tatik, et al 2019) proposes an innovative motorcycle security system that uses Internet of Things (IoT) technologies to prevent theft, a common problem in urban areas such as Jakarta.

The system is designed to be an effective and accessible solution, using components such as the Arduino Mega2560 microcontroller, a fingerprint sensor, and the ESP8266 communication module, along with the Blynk application for notifications on smartphones, the main objective of the system is to provide an additional layer of security to motorcycles by biometric verification of the user. This is achieved by ensuring that only authorized persons can start the motorcycle engine, which is verified through a fingerprint sensor.

Theoretical framework

In the last decade, vehicle theft has been steadily increasing, which is increasingly noticeable, since each of us has been a victim or knows someone who has experienced it, the impacts of vehicle theft have drastically affected social security and the economic condition of the whole world due to the lack of an adequate system that can integrate technology in commercial cars, or that the majority of the population has (low-end) (Das, et al 2021).

The project focuses on the areas of car security and technology. Today, high rates of insecurity are causing a significant increase in vehicle theft, which is undermining the economy of Mexicans, as well as SMEs (Small and Medium Enterprises), due to the absence of an effective anti-vehicle theft system, see table 1.

According to the AMIS (Mexican Association of Insurance Institutions) report from 2020, published in (AMIS, n.d.). An average of 167 vehicles are stolen every day in Mexico.

From October of last year to September 2020,60,905 insured vehicles were stolen in the country, according to the most recent figures shown in Table 1, although people's mobility increased in 2019 compared to 2020, after the relaxation of health measures, vehicle theft fell 2.7% compared to the previous 12 months.

In this period, AMIS estimates that 26,554 stolen vehicles were recovered, which meant an annual decrease of 8.2%, however, out of every 10 thefts, six were carried out with the use of violence, as shown by figures provided by the organization. Among the states with the most types of thefts from insured vehicles, the State of Mexico is in first place, followed by Jalisco, Mexico City, Puebla, Guanajuato and Veracruz.

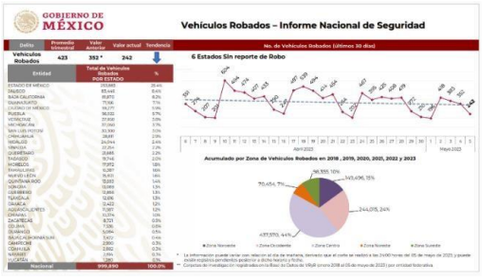
Among the 10 most stolen models, four are from the Nissan brand (Versa, Tsuru, March and Sentra), two from General Motors (Aveo and Beat), two from Honda (CR-V and HR-V) and two more from Volkswagen (Jetta and Vento).

In Mexico there is the Specialized Unit for the Investigation of Assault and Theft of Vehicles (UEIARV), which is attached to the Specialized Subprosecutor's Office for the Investigation of Organized Crime (SEIDO) and on its official website it mentions that for several years the crime of vehicle theft has increased, due to the fact that criminal organizations increasingly use stolen vehicles (which they themselves steal in different states of the Republic), to carry out their illicit activities.

Box 1

Table 1

Theft of insured vehicles



Source: report sept2019-ago2020 AMI

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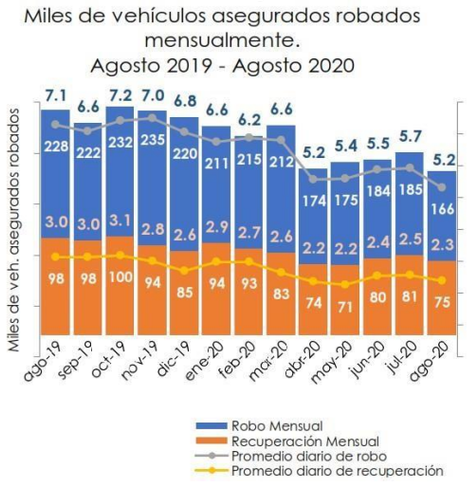
Box 2

Table 2

Stolen vehicles as of May 2023



Source: January 2018 to May 5, 2023

Methodology to be developed

Electronic circuit design

One of the best alternatives to develop the Project is to use the Arduino Platform, which is one of the most versatile on the market, affordable and open source, in addition to having one of the largest collaboration networks, through forums and channels on different social networks, in Figure 1.

The variants of Arduino commercial cards are shown.

Box 3

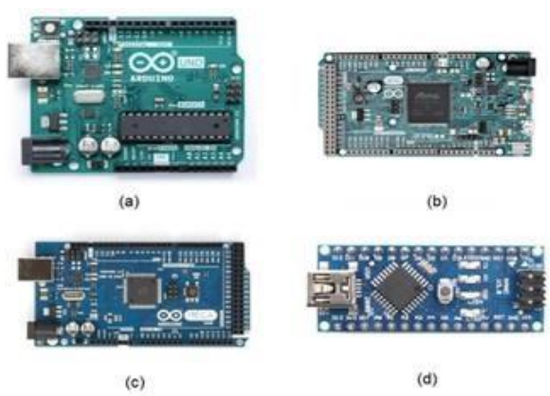


Figure 1

Arduino variant boards (a) Ard. UNO (b) Ard. Due (c) Ard. Mega (d) Ard. Nano

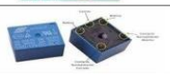
Source: own elaboration

To complement the list of components to assemble the control circuit for the Project, the following components are added:

Box 4

Table 3

Components for the control circuit

Cantidad	Descripción	Imagen	Costo
1	Arduino		$140.00
1	Relevador		$80.00
1	Sensor de Huella AS606		$236.00
1	Batería de 12V		$850.00
1	Motor 12V		$80.00
1	Buzzer		$7.00

Source: own elaboration

The electrical circuit connection diagram is shown in Figure 2, where we can see an Arduino UNO card, a fingerprint reader, basically, but a power supply is also required (for this stage of project development, a 12 Volt DC power supply is being used, but it is intended to use the automotive battery of the same vehicle in which the system is tested), a 12 volt relay, which is enough to have a control circuit as mentioned (R. Thanuj, et. al. 2023), in addition to its respective code.

Box 5

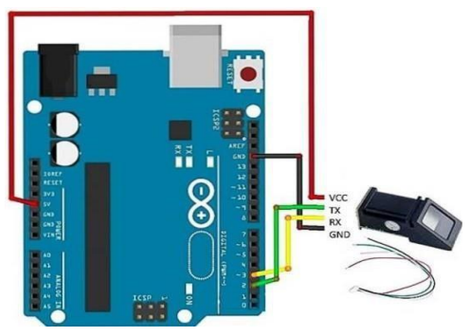


Figure 2

Electrical diagram of the control circuit

Source: own elaboration

The fundamental part of the control circuit is the microcontroller (Veeramanickam, et. al. 2022), which is intended to process the different signals, according to the model, particularly for the project, are the signals sent by the fingerprint sensor, who will be in charge of receiving (scanning) and emitting status validation signals (comparing against the previous record in the database), part of the fingerprint reading control code, is shown in Figure 3.

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Box 6

```
finger.getTemplateCount();
Serial.print("El sensor contine"); Serial.print(finger.templateCount);
Serial.println("plantillas");
Serial.println("Esperando por una huella valida...");
}
void loop()
{ analogo5=analogRead(A5);
If(analogo5<=800){
Serial.print("Salida
Interna *** ");
encenderm ();
}
getFingerprintIDez ();
delay(50);
```

Figure 3

Fingerprint reading control code fragment

Source: own elaboration

Physical installation of the components

The fingerprint sensor was installed in a model, simulating the dashboard of a vehicle, for practical, economic and fast data generation reasons, where the steering wheel and the fingerprint reader are presented, which scans the user's fingerprint beforehand registered.

As well as the complete circuit including all the components described in Table 3, as shown in Figures 4 and 5.

Box 7

Figure 4

Automotive dashboard simulation test model

Box 8

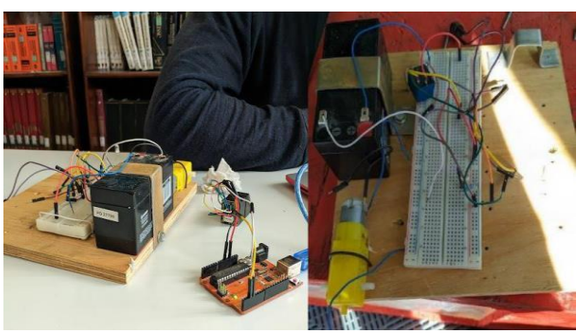

Figure 5

Fingerprint ignition control circuit

Results

As a result of the integration of different digital technologies and applications between different systems, users of low- and mid-range compact cars can prevent and avoid the theft of a conventional car, in vehicles that do not have any built-in electrical system (low-range), and even some that only have built-in presence sensors (mid-range), as well as cars depreciated with respect to 2024.

Specifically for the particular case of vehicle theft prevention, the most important thing is to prevent the vehicle engine from being started, which is why the design of digital ignition control of compact vehicle engine, was developed with the elements described in the Table 3, but during development the problem of code integration arose, since there is a main code, but the manufacturer of the fingerprint sensor also offers a code with which the fingerprints of the users who want to have access to the vehicle's engine ignition control system must be enrolled (registered).

Box 9

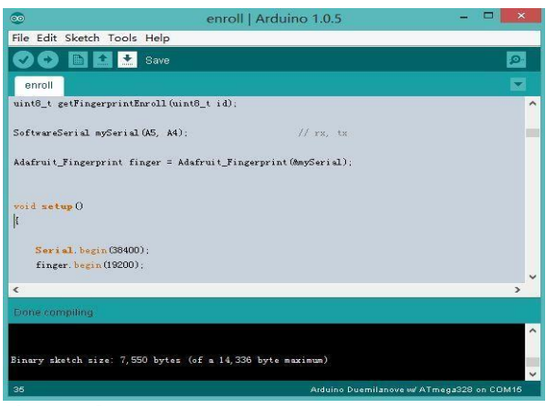

Figure 6

Arduino code snippet for fingerprint enrollment

Source: own elaboration

The time to register a new fingerprint is approximately 5 minutes, but it is highly recommended that before registering, the user properly cleans the surface of the finger that he wants to register; it is sufficient to wash it with soap and water beforehand; and also to make sure that it does not have any scratches, wounds or ink stains or any substance or material foreign to human tissue.

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Conclusions

As part of the actions to prevent vehicle theft, conditions can be implemented, such as having a garage with a very good lock, steering wheel immobilizers, audible or visual alarms, among others, but current conditions of insecurity require the use of technologies and, much better, combining and integrating them to strengthen an anti-theft protection or prevention system, which is intended to be designed based on commercial and low-cost technologies such as the Arduino platform, using fingerprint sensors and open source programming, which can be simulated before implementing in prototypes or final systems, as well as the design, creation and integration of applications that are compatible with the Arduino platform.

The main objective of this work was to develop an engine ignition control system for a vehicle that has very limited or no factory technology conditions, depending on the model and make, such as low-end vehicles, and which is a quite vulnerable and abandoned sector, which causes such cars to depreciate much faster than expected, but above all the system was designed with the mission of offering a technological security alternative for the vehicle, of the average owner in Mexico, which is economical, intuitive and up-to-date that can integrate and complement any vehicle that the owner has, without the need to invest in specific models or brands and above all obtaining the same technological security advantages as if you had a high-end vehicle. In a future project, the implementation of this engine ignition control system is being considered. The selected vehicle is a Nissan Tsuru model, with VIN number: 3NIEB3IS03K506364.

All the researchers working on this project are pleased to know that we have managed to contribute to reducing the high theft rates that are increasing every day, alerting and worrying Mexicans, due to the low blow that this represents for their family economy and for the MSMEs.

Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Authors' contribution

Guzmán-Cortés, Agustín: Prototype, Contributed with the main idea and the writing of the article.

Barbosa-Santilla, Luis Francisco: Implementation, contributed with the implementation of the technology.

Gonzalez-Contreras, Brian Manuel Methodology, contributed with the methodology applied for the development of the research.

Alvarez-Gonzalez, Ricardo: Translation, contributed with the translation of the article

Data availability

Registration is required to access the databases consulted

Funding

The Technological University of Puebla only contributed to the payment of the publication of the article

Abbreviations

DAS (Driving Assistance System)
ECU (Electronic Control Unit)
AMIA (Mexican Association of the Automotive Industry)
LCD (Liquid Crystal Display)
GPS (Global Positioning System)
IDE (integrated development environment)
IoT (Internet of Things)
SEIDO (Specialized Subprosecutor's Office for the Investigation of Organized Crime)
UEIARV Specialized Unit for the Investigation of Assault and Theft of Vehicles
SMEs (Small and Medium Enterprises)

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