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Article

Autotronic system for vehicle and pedestrian detection using Artificial Intelligence

Sistema autotrónico de control para detección de vehículos y peatones mediante inteligencia artificial

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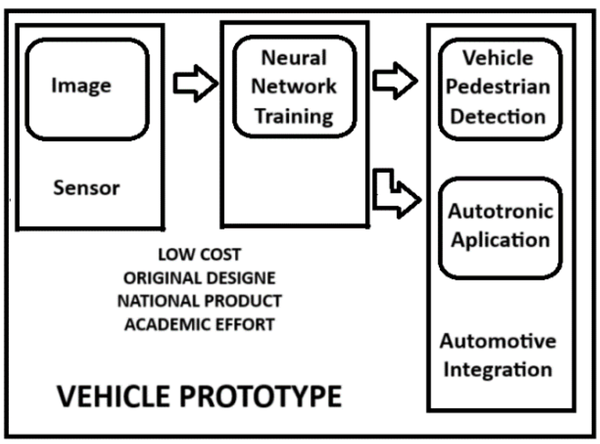
Abstract

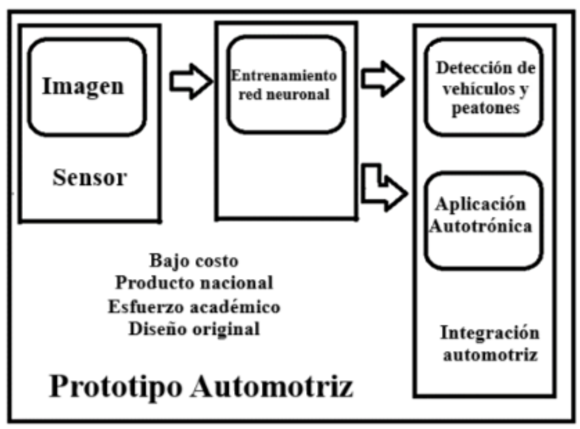
The project is based on artificial intelligence which is focused on the detection of pedestrians and vehicles by means of a camera installed in the user's vehicle. Currently, the technological trend is mostly focused on autonomous vehicles, which seek to generate greater convenience and comfort for the driver. Due to the fact that drivers are usually very distracted and are not aware of the road and what is happening around their vehicle, thus causing road accidents. Road culture is not very present in most places where motor vehicles circulate, in addition to the various forms of distraction that currently exist. For that reason, a way to avoid as much as possible these automobile accidents were developed, thus opting for the new available technologies such as Artificial Intelligence and development boards dedicated to image processing.



Autonomous, Detection, Generate, Technologies, Development, Processing, Pedestrians

Resumen

El proyecto está basado en inteligencia artificial la cual va enfocada a la detección de peatones y vehículos por medio de una cámara que se instaló en el vehículo del usuario. Actualmente la tendencia tecnológica va enfocada en su mayor parte a los vehículos autónomos, los cuales buscan generar una mayor comodidad y confort en el conductor. Debido a la que los conductores suelen ser muy distraídos y no estar al tanto del camino y de lo que ocurre alrededor de su vehículo provocando así accidentes viales. La cultura vial no suele estar muy presente en la mayoría de lugares donde se circula con vehículos automotores, además de las diversas formas de distracción que existen actualmente. Para eso se desarrolló una manera de evitar lo más posible estos siniestros automovilísticos, así optando por las nuevas tecnologías disponibles como lo es la Inteligencia Artificial y placas de desarrollo dedicadas al procesamiento de imágenes.



Autónomo, Detección, Generar, Tecnologías, Desarrollo, Procesamiento, Peatones

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Introduction

Today, the development of autonomous or partially autonomous vehicles is a reality thanks to companies like Tesla, BYD, and Toyota, to name a few. It will become increasingly common to find these vehicles, which implement this type of technology, on the streets.

The development of projects based on artificial intelligence is already a fact, as this type of technology is currently accessible to anyone and relatively easy to program. In this case, the project used AI focused on the detection of pedestrians and vehicles through a camera that will be installed in the user's vehicle.

The project's goal is to provide both safety and comfort to the driver by monitoring what is happening around their vehicle and, based on the surroundings, enabling various functions as needed. This is achieved using the Raspberry Pi 4 board, which offers great video processing capabilities for the project.

This project is of great importance for the implementation of new technologies in vehicles and achieving increasingly self-sufficient systems, which will allow for a more complete and enjoyable driving experience without the need to be alert at every moment while driving.

Background

Computer vision systems are essential in industrial automation tasks such as identification, selection, measurement, defect detection, and quality control of parts and components.

Intelligent cameras are employed for these tasks; however, their high acquisition and maintenance costs can be prohibitive. This paper proposes an innovative, low-cost artificial vision system for real-time object classification, using the embedded system Raspberry Pi 3B+, a web camera, and the OpenCV computer vision library. The suggested technique involves training a supervised classification system of the Haar Cascade type, using custom image databases of the objects to be recognized, and subsequently generating a predictive model that is tested with real-time detection and prediction error calculation.

The goal is to build a powerful, affordable vision system that is also developed using open-source software shown in Figure 1 (Serrano-Ramírez, *et al*., 2021).

Box 1

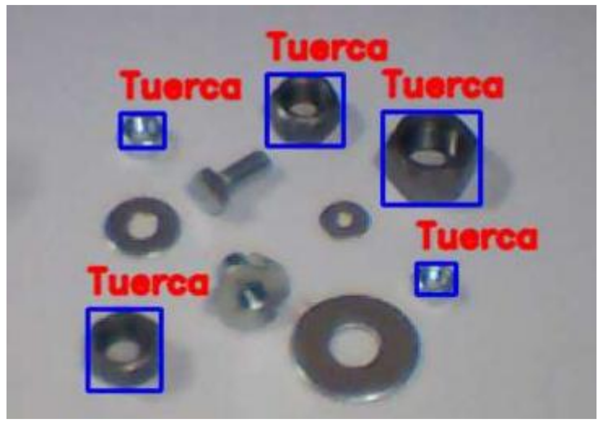

Figure 1
Object classification

Source: Serrano-Ramírez, et al., 2021

The automotive industry has been around for quite some time and has constantly evolved, but the major transformation that is happening now, from human-driven vehicles to self-driving vehicles, will have a long-term impact on society. Today's cars are already connected and have been for some time, as they can link to smartphones, offer roadside assistance in case of emergencies, record real-time traffic alerts, etc., but this evolution is about to change as shown in Figures 2.

As shown in Figure 1, the automotive industry is on the brink of a revolution, shifting to an autonomous vehicle industry, with the driving force behind this being rapidly developing technology, the Internet of Things (IoT). IoT will transform the automotive industry, and at the same time, the automotive industry will provide a significant boost to IoT. The potencial and prospects of this technology are astonishing (Wang, C et al., 2016).

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Box 2

Figure 2
Autonomous vehicles evolution

Source: Wang, C et al., 2016

The vision of autonomous vehicles has a long history. In 1925, a prototype of a radio-controlled vehicle was demonstrated by the "Linrrican Wonder" in New York. Since then, autonomous driving has been a topic of science fiction and, more recently, within engineering science. Major car manufacturers and players from other industries have announced their intention to introduce fully automated cars within the next 10 years.

Autonomous driving is, therefore, on its way to market entry. It requires a set of high-end technologies both in vehicles and in infrastructure that are comprehensively connected or even integrated. A key technology for autonomous driving is, for example, the real-time high-definition (HD) map, as shown in Figure 3 (Liu, Q et al., 2016).

Box 3

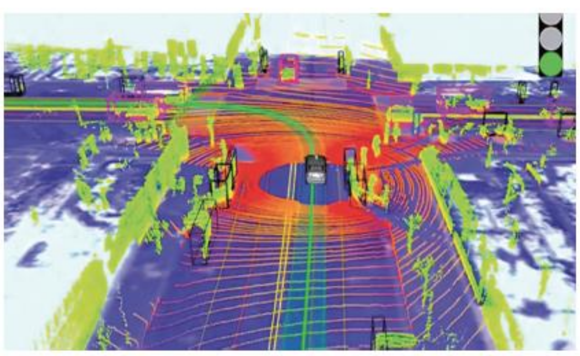

Figure 3
High-definition map in real time
Source: Liu, Q et al., 2016

The simulation of pedestrian movement in urban traffic networks is crucial for designing autonomous vehicle systems, as shown in the example in Figure 4. In a mixed traffic system, a complex interaction occurs between a pedestrian and a vehicle. To understand this interaction pattern and evaluate traffic safety analysis, a simulation tool can be useful. It can help autonomous vehicle designers visualize the trajectories of pedestrians and vehicles, extract the velocity and acceleration profiles of both agents, test different autonomous vehicle planning algorithms, and assess traffic safety in severe traffic conflicts (Md Mobasshir Rashid et al., 2024).

Box 4

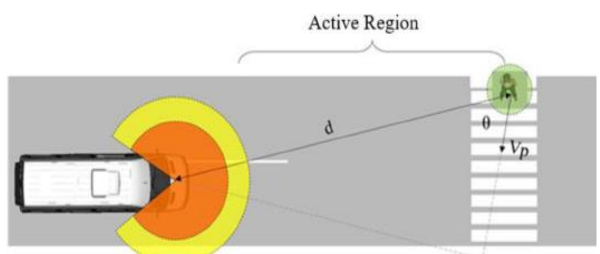

Figure 4
Autonomous vehicles environment simulation

Source: Md Mobasshir Rashid et al., 2024

Materials and methods

The detection process was carried out according to the block diagram shown in Figure 5.

Box 5

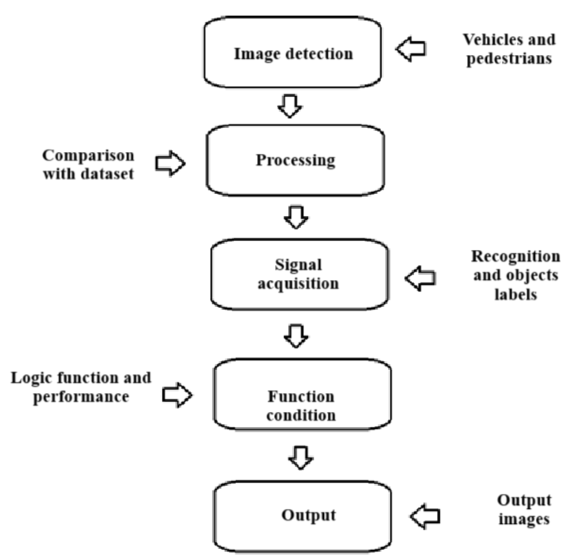

Figure 5
Project block diagram

Source: Own elaboration

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For the development of the project, the YOLOv5 neural network was used, which is a free and easy-to-use resource for machine learning. Ultralytics YOLOv5 is a state-of-the-art (SOTA) model that builds on the success of previous versions of YOLO and introduces new features and improvements to further enhance performance and flexibility. YOLOv5 is designed to be fast, accurate, and easy to use, making it an excellent choice for a wide range of tasks, including object detection, instance segmentation, and image classification (Zhang, Y., & Li, H., 2023).

Additionally, development boards like the Raspberry Pi 4 were used, which is a low-cost, compact-sized computer. It is a small computer that runs a Linux operating system, enabling people of all ages to explore computing and learn to program in languages like Scratch and Python. Besides having the ability to interact with the outside world, it can be used in a wide variety of digital projects. This board was used to conduct the initial functionality tests.

Once the program was stable and functioning, it was migrated to the Raspberry Pi 4 development board.

Neural network training YOLOv5

For the training, a dataset was created, as shown in Figure 6, consisting of various images of pedestrians and different vehicles that can be found on public roads from different angles and situations, to ensure that the training is as precise and optimal as possible (Dong, X et al., 2022).

Box 6

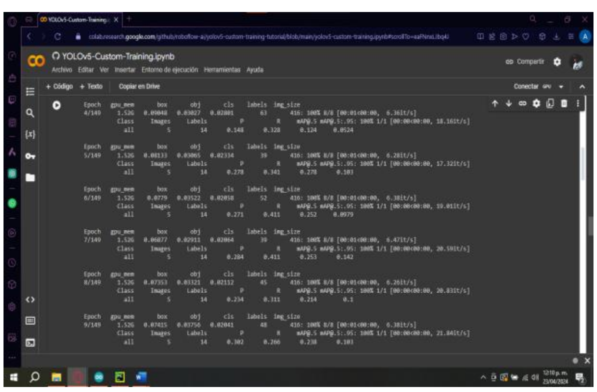

Figure 6
Neural network training

Source: Own elaboration

Once the neural network was trained, a simulation was conducted in a controlled environment using our computational system for object detection, specifically pedestrians and vehicles, as shown in Figure 7. This test was successful, as it managed to simultaneously detect pedestrians and vehicles, concluding the first part of the project as shown in Figure 7.

Box 7

Figure 7
Object detection test

Source: Own elaboration

Subsequently, a command was added to the code to identify the position of objects within the camera's field of view, as shown in Figure 8.

Box 8

Figure 8
Object position detection

Source: Own elaboration

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Circuit design and connection

As a first step toward obtaining signals, a simple circuit was created with the help of the ESP32 and Arduino, as shown in Figure 9. This circuit indicates the type of object detected and its position using LEDs.

To achieve this, an algorithm was developed to handle the signal transmission from the Python code, as shown in the flowchart in Figure 10.

The circuit serves as an interface between the digital part and the actuators, integrating the algorithm with the outputs of the vehicle's autotronic system.

The signals visualized in Figure 9 will serve as control signals for the vehicle's electric motors, thereby enabling the implementation of intelligent routines for object, pedestrian, and other vehicle avoidance. The autotronic prototype is an autonomous system based on artificial intelligence.

Box 9

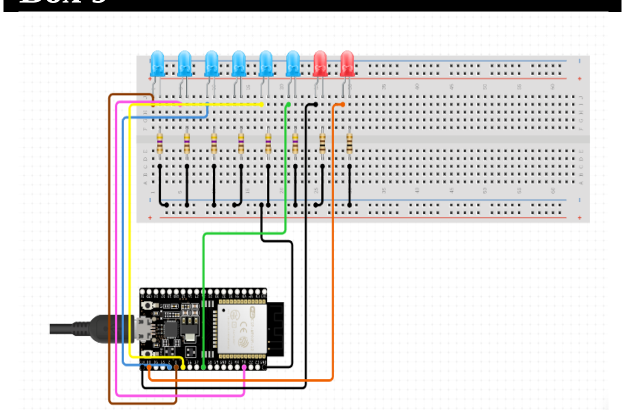

Figure 9
Circuit diagram

Source: Own elaboration

Box 10

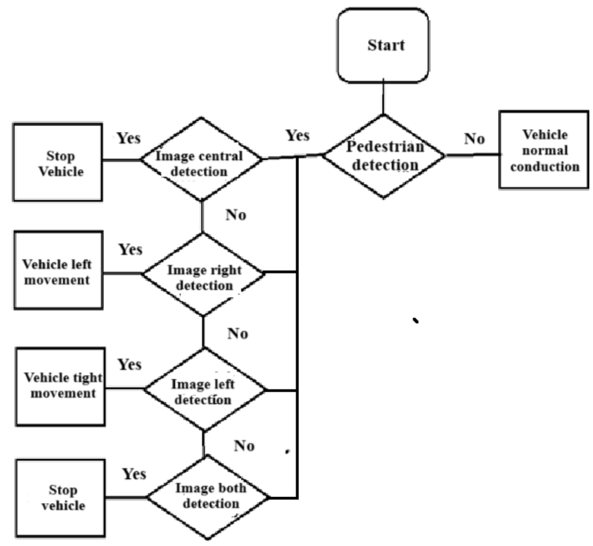

Figure 10
Algorithm

Source: Own elaboration

Signal acquisition

To obtain the signals, a code developed in Arduino was used. This code is loaded onto the ESP32, which will receive data via the serial port. The data sent are character-based, indicating the position of the object depending on whether it is a vehicle or a pedestrian. The data are classified as follows:

Box 11

Table 1
Data available for training

For pedestrians:
I = Left
D = Right
M = Middle

Source: Own elaboration

Box 12

Table 2
Data available for training

For vehicles:
L = Left
R = Right
C = Center

Source: Own elaboration

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In addition to the two other data points used to activate indicator LEDs, which light up if no detection is recognized. The data are E and N, where E indicates that no pedestrians are detected and N indicates that no vehicles are detected.

Signal processing

Important features acquired from the images are parameters used for training, such as shape, position, colors, and size of the objects. These parameters are used for training the neural network. With the data classified, testing is carried out to observe proper functioning, as shown in Figures 11, 12, and 13.

Box 13

Figure 11
Pedestrian detection test

Source: Own elaboration

Box 14

Figure 12
Vehicle detection test

Source: Own elaboration

Box 15

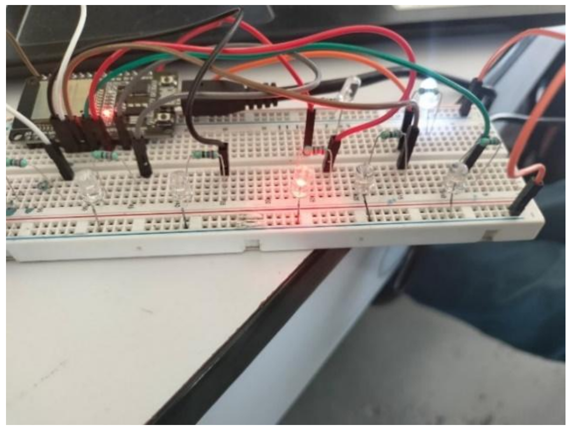

Figure 13
LED´s activation

Source: Own elaboration

When a detection occurs, the designated LED lights up, considering the position and type of the object, and the indicator LED for no detections turns off. Figure 9 shows the pedestrian LED on the left.

Raspberry Pi 4 migration

After completing the tests with serial communication using the ESP32, the next step was to migrate to *Raspberry Pi* 4, to consolidate the process into a single hardware unit [6]. The first step was to install all the necessary requirements for the model to function [6]. With this completed, the model was executed on the Raspberry Pi 4, as shown in Figures 14 and 15, to observe its performance in the system. It was observed that there was a limitation in processing power from the board's CPU, as YOLOv5 is not optimized for use on this board. Figure 10 shows the model running on the Raspberry Pi 4.

Box 16

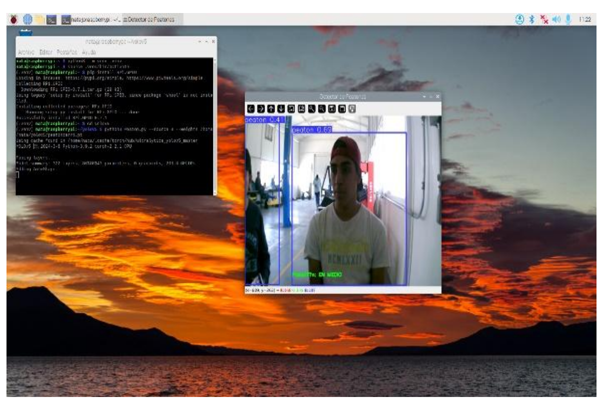

Figure 14
Performance system

Source: Own elaboration

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Raspberry Pi 4 development

To use the GPIO ports on the Raspberry Pi 4, it was necessary to understand the pin nomenclature shown in Figures 15 and 16, as unlike other boards, the Raspberry Pi 4 does not have a labeled pinout.

Box 17

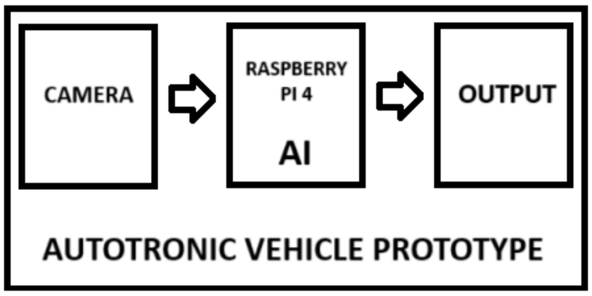

Figure 15
System block diagram

Source: Own elaboration

Box 18

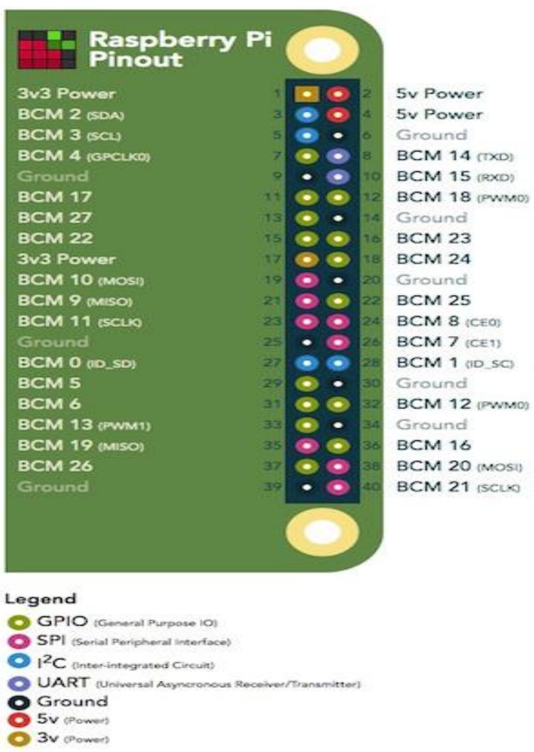

Figure 16
Raspberry pi IN/OUT

Source: Own elaboration

Once the pins were identified, the same LEDs used with the ESP32 were employed, so the previously used variables were replaced with the pin numbers, as shown in Figure 17:

Box 19

Table 3
Control variables

E=18	N=3
I=11	L=29
D=13	R=31
M=15	C=33

Source: Own elaboration

To do this, we based our work on the following diagram.

Box 20

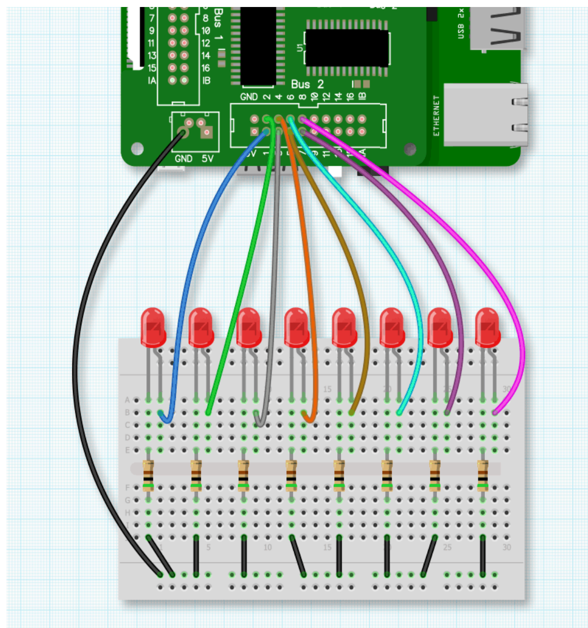

Figure 17
Raspberry pi connection
Source: Own elaboration

Results

The implementation of this project achieved the desired results, as the main idea was to perform the entire process using a single embedded system.

In this case, the entire process was carried out using the Raspberry Pi 4, which managed to complete the process despite some hardware limitations.

The obtained signals were as desired, and are presented as shown in Figures 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28 and 29.

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Box 21

Figure 18
Raspberry pi pedestrian detection

Source: Own elaboration

Box 22

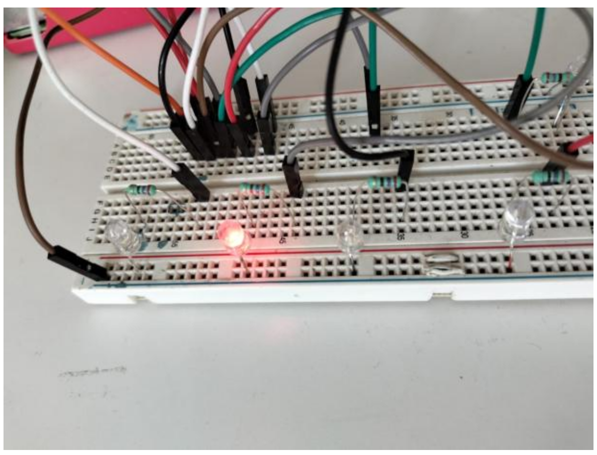

Figure 19
Signal OUT pedestrian detection

Source: Own elaboration

Box 23

Figure 20
Raspberry pi left pedestrian detection

Source: Own elaboration

Box 24

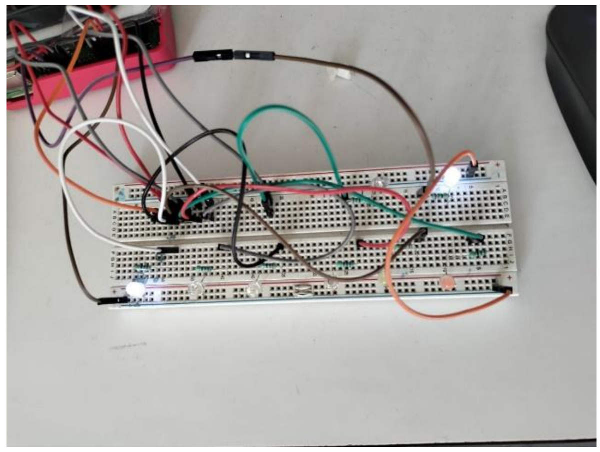

Figure 21
Signal LED left pedestrian detection

Source: Own elaboration

Box 25

Figure 22
Raspberry pi right pedestrian detection

Source: Own elaboration

Box 26

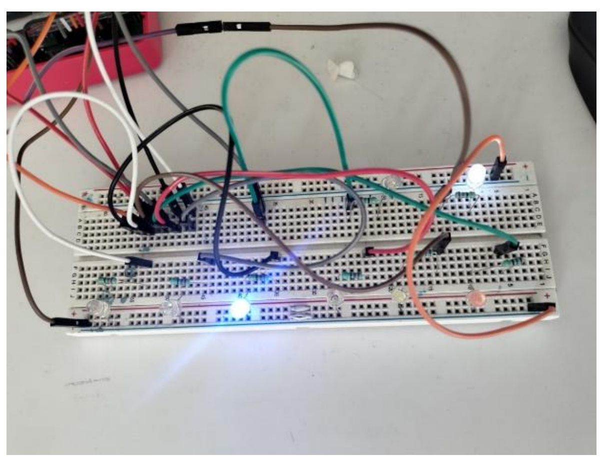

Figure 23
Signal LED right pedestrian detection

Source: Own elaboration

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Box 27

Figure 24
Raspberry pi center vehicle detection

Source: Own elaboration

Box 28

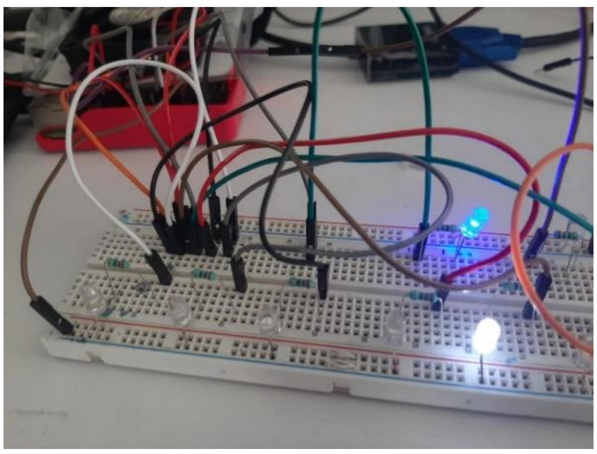

Figure 25
Signal LED center vehicle detection

Source: Own elaboration

Box 29

Figure 26
Raspberry pi center vehicle and pedestrian detection

Source: Own elaboration

Box 30

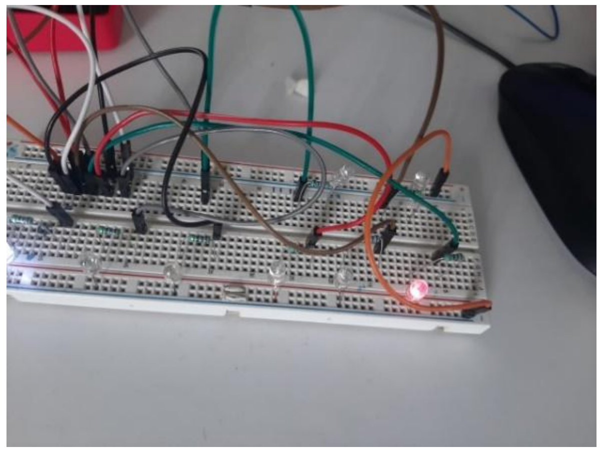

Figure 27
Signal LED right vehicle detection.

Source: Own elaboration

Box 31

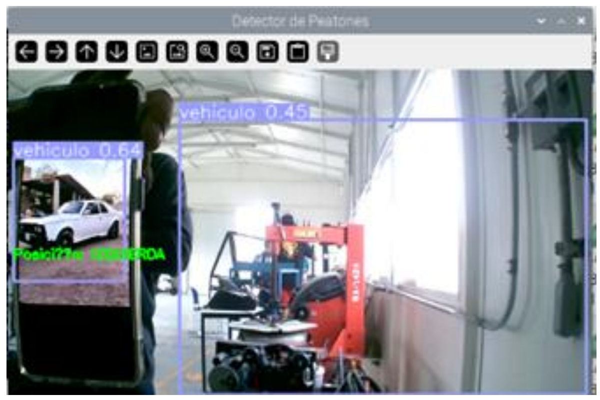

Figure 28
Raspberry pi left vehicle detection

Source: Own elaboration

Box 32

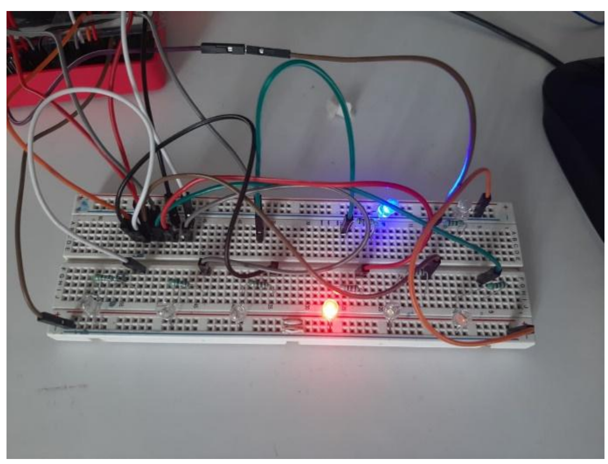

Figure 29
Raspberry pi left vehicle detection 4.

Source: Own elaboration

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Discussion

One of the most important problems in the world is contamination and the correct use of energy, including the use of sustainable energy sources.

Electric and autonomous vehicles are both developments within the same field, electromobility. One of the most challenging issues in this area is the infrastructure for charging, distribution, and energy acquisition.

We need to address the generation and distribution of electrical energy to advance the development of autonomous and electric vehicles. However, one thing is certain: these technologies represent the future of transportation.

Another significant issue to solve is achieving 100% autonomy. It is very difficult to create a system that is functional in all environments worldwide, which is why a fully autonomous vehicle is not yet available on the market.

The academic contribution is to offer more systems that can be used to build solutions addressing these proposed problems.

Conclusions

This project represents an advancement in object detection, which in the future could be applied to automotive systems. It could contribute to the development of increasingly self-sufficient systems, as well as more reliable safety systems, to enable a more enjoyable driving experience.

Today the electric and autonomous vehicles are the technology evolution, That need to development systems capable to compete in the market. The academic and industrial effort must be focused in the engineering design, development and construction this king of technology

Improvements could be made to enhance the functionality of our program, allowing it to perform additional functions or to utilize systems with better specifications capable of real-time object detection.

Conflict of interest

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

Authors' Contribution

The contribution of each researcher in each of the points developed in this research, was defined based on:

Sámano-Flores Yosafat Jetsemani: Contributed to mentorship of the team and acquisition of material, also Oriented the development and understanding of the project, He also worked on the writing of the paper.

Serrano-Rámirez Tomás: Contributed to mentorship of the team, He motivated the development of the project by being an example in the field, an excellent developer.

Vargas-Torres Antonio: Contributed to the research design, development, and the construction of technical part of project, always with the best attitude.

Campos-Hernandez Juan Salud: Contributed to the research design, development, and the construction of technical part of project, always with the best attitude.

Availability of data and materials

The images for the integration of the system were obtained from Laboratories and Materials from department of Automotive Engineering from Universidad Politécnica de Guanajuato

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Abbreviations

BYD	Build Your Dreams
IoT	Internet of Things
YOLO	You Only Looks Ones
HD	High Definition
ESP32	Espress Systems
CPU	Central Prossesing Unit
GPIO	General Porpouse Input/Output
AI	Artificial Intelligence

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Basics

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Supports

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