Article
Journal Applied Computing
December 2023, Vol.7 No.21 17-22

Pedestrian detection system for automobiles using computer vision and artificial intelligence using *Raspberry Pi* 4 and webcam

Sistema de detección de peatones para automóvil mediante visión por computadora e inteligencia artificial empleando *Raspberry Pi* 4 y cámara web

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DOI: 10.35429/JCA.2023.21.7.17.22 Received July 10, 2023; Accepted December 30, 2023

Abstract

Traffic accidents involving pedestrians have increased in recent years, causing a large number of deaths worldwide, some of the main causes being: distracted drivers or pedestrians, car blind spots, adverse environmental conditions among others. With the advent of autonomous driving systems at different levels, the development of pedestrian detection systems has become a priority task. In this work, an economical and easy-to-install pedestrian detection system for automobiles is proposed, which uses the Raspberry Pi 4 card, webcam and an LCD screen as hardware. In the software part, a computer vision system with artificial intelligence is implemented using the TensorFlow Lite library for the classification of people in real time, Python and Open CV as programming language and computer vision library. The aim is for the system to visually alert the driver about the presence of pedestrians on both sides of the road or that get in the way of driving in order to avoid possible accidents.

Pedestrian detection, TensorFlow, *Raspberry Pi*

Resumen

Los accidentes de tránsito que involucran peatones, se han incrementado en los últimos años, causando un gran número de muertes a nivel mundial, siendo algunas de las principales causas: conductores o peatones distraídos, puntos ciegos en el automóvil, condiciones ambientales adversas, entre otras. Con el advenimiento de los sistemas de conducción autónoma en sus diferentes niveles, el desarrollo de sistemas para la detección de peatones se ha vuelto una tarea prioritaria. En este trabajo se propone un sistema de detección de peatones para automóvil económico y de fácil instalación, el cual utiliza como hardware la tarjeta Raspberry Pi 4, cámara web y una pantalla LCD. En la parte del software se implementa un sistema de visión por computadora con inteligencia artificial utilizando la librería TensorFlow Lite para la clasificación de personas en tiempo real, Python y Open CV como lenguaje de programación y librería de Visión por computadora. Se busca que el sistema alerte al conductor de forma visual sobre la presencia de peatones a ambos lados del camino o que se interpongan en la trayectoria de conducción con el objetivo de evitar posibles accidentes.

Detección peatones, TensorFlow, *Raspberry Pi*

Citation: SERRANO-RAMÍREZ, Tomás, SÁMANO-FLORES, Yosafat Jetsemaní, GUTIERREZ-LEÓN, Diana Guadalupe and BARRIENTOS-GARCÍA, Alejandro. Pedestrian detection system for automobiles using computer vision and artificial intelligence using *Raspberry Pi* 4 and webcam. Journal Applied Computing. 2023. 7-21:17-22.

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Introduction

According to the World Health Organization (World Health Organization, 2022), globally 1.3 million pedestrians die each year as a result of road traffic crashes and between 20 and 50 million more suffer non-fatal injuries, which in a significant percentage of cases result in permanent disability. There are several factors that contribute to these accidents, including driving errors, vehicle malfunctions, environmental factors such as poor signage, lack of pavements or poor lighting conditions. In addition, the pedestrian is also a major contributor (Hasan and Hasan, 2022), due to the increase of distractors such as the use of portable IoT devices on the road such as smartphones, headphones, among others.

Although the statistics are alarming, with the advent of driver assistance technologies such as Autonomous Emergency Breaking (AEB) and pedestrian detection systems, a 25%-27% reduction in pedestrian hit-and-run risk is achieved (Cicchino, 2017).

Different technologies have been implemented in automobiles for pedestrian detection including: ultrasonic sensors, piezoelectric sensors, microwave radar, Laser Imaging Detection and Ranging (LIDAR), Infrared IR sensors and Computer Vision (Chan and Bu, 2006).

Of these technologies, computer vision has taken a leading role in pedestrian detection, due to the emergence of new and increasingly efficient artificial intelligence algorithms, embedded systems with sufficient computing power to process such algorithms in real time, and the economy of conventional digital camera sensing. In addition, computer vision systems emulate the functioning of the human eye-brain vision system, which has proven to be extremely efficient.

Computer vision methods for pedestrian detection have undergone two stages of evolution (Han et al., 2021), the first of which covers the period 2001 to 2013, corresponding to detection using classical pattern recognition algorithms.

In this stage, the procedure consisted of processing the images obtained by the digital camera one by one, first implementing algorithms to improve the quality of the image, then applying algorithms for feature extraction such as Haar or Histogram of Oriented Gradients and then using pattern recognition algorithms such as Support Vector Machine or Decision Tree for the prediction of the object, in this case the pedestrian. The disadvantage of such an approach is the requirement of considerable computational power and poor classification performance.

The second stage consists of the period from 2014 to the present, which is highlighted by the implementation of Convolutional Neural Networks (CNN) in computer vision and pedestrian detection systems. This brought a considerable improvement, because CNNs are computationally efficient, automatically optimise model parameters, automatically extract features and above all, are highly accurate in classifying objects in images.

Nowadays, due to the increased processing power of single-board computers and the efficiency of CNN-based computer vision systems, it is possible to implement pedestrian detection systems for driving assistance, which are not only distinctive of high-end cars, but can be installed in any car at a competitive cost and with high performance.

The proposed system is in line with this approach, employing as sensor an inexpensive webcam with a resolution of 1.3 Mega pixels and data transmission via USB 3.0. For video processing the Raspberry Pi 4 embedded system is used, a single board computer the size of a bank card which has the following features: a quad-core processor at 1.8 GHz and 64 bits, 4GB LPDDR4 ram memory, two USB 3.0 ports, two USB 2.0, HDMI, WiFi, Bluethooth, 40 GPIO input and output pins, among others.

On the software side, a model pre-trained by Google for object detection based on CNN and implemented using the TensorFlow library is used, as well as the Python 3 programming language, the OpenCV computer vision library and the Raspberry OS operating system, giving preponderance to the use of free software.

ISSN-2531-2952

Hardware development

The following is a list of the equipment used for the realisation of this project:

- Logitech C920 webcam.
- Raspberry Pi 4 with 4GB of RAM.
- 10.1 inch LCD monitor.
- 120 W power invertir.
- Wireless keyboard and mouse.

A Logitech C920 3 megapixel Full HD 1080p 30 fps webcam was used, which is responsible for capturing the video signal in the pedestrian detection system. The camera was selected for its sensor quality, its ability to adjust luminance for different light conditions, auto focus and 78° viewing angle.

The camera was installed on the sunroof of the car pointing forward in order to capture the video feed from the road, similar to what the driver would see. Figure 1 shows the camera and its installation position in the car.

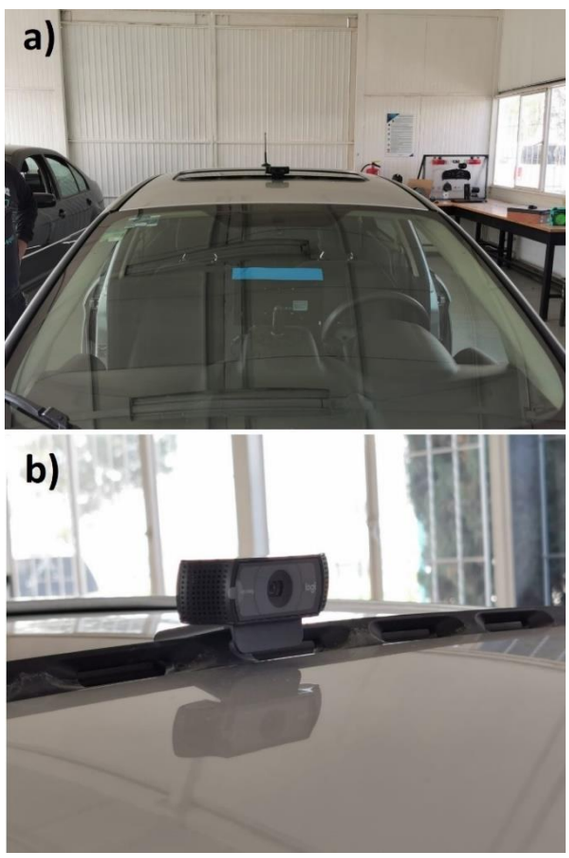

Figure 1 Logitech C920 webcam and its installation on the sunroof of the car to capture the video signal, a) front view and b) side view

A Raspberry Pi 4 single board computer was installed inside the car cabin, which is powered by a 120 W inverter connected to the battery. In turn, the computer was remotely controlled by a wireless keyboard and mouse. Figure 2 shows the Raspberry Pi board, the inverter and its installation inside the car.

Figure 2 Raspberry Pi 4 board mounted inside the cabin of the car and powered by an inverter connected to the battery

The Raspberry Pi 4 board was in charge of running the pedestrian detection system implemented through Artificial Intelligence, remembering that this is a complete computer controlled by the Raspberry Pi OS operating system, which manages the execution of the detection model.

Next, a 10.1-inch colour LCD monitor connected to the Raspberry Pi was used to provide real-time feedback on the detection of pedestrians on the road and the possible alerts derived from it. It was placed inside the cockpit, on the dashboard and facing the driver (Figure 3).

ISSN-2531-2952

Figure 3 In-dash colour LCD screen, which displays real-time pedestrian detection on the road and corresponding alerts

Software development

For the development of the pedestrian detection system, the implementation of its components was contemplated using free software, with the advantages that this entails, so the use of open source libraries and programmes is a priority. Below is a list of the programs used for the implementation of this project:

- Raspberry Pi OS
- Python 3
- Open CV
- TensorFlow Lite

The first step consisted of installing the Raspberry Pi OS operating system on the Raspberry Pi 4 board. As this is a small board computer, the OS is necessary for the management of all processes and programs. The second step involved the installation of the Python 3 interpreter, in which the pedestrian detection system will be programmed. Python is a modern high-level programming language, used for the creation of free software, which does not require compilation, thus reducing testing and debugging time.

The third step consisted of installing Open CV, a computer vision library whose function is to capture and process the video signal, providing a set of basic functions for mathematical image processing, colour space shifting and pixel manipulation.

The fourth step involved the installation of TensorFlow Lite, an open source library developed by Google to implement deep learning models on resource-constrained edge devices. TensorFlow Lite models have a faster inference time and require less processing power, so they can be used for faster performance in real-time applications.

Once the necessary software components have been installed, the pedestrian detection system is developed, using as a basis the model trained by Google and developed using the TensorFlow Lite library for object recognition; this model is based on deep neural networks.

As soon as the model receives the video stream, the system classifies the objects for which it was trained and provides the position in the image. Among the objects it can classify (73 different types of objects) are people, cars, vans, motorbikes, chairs, tables, among others. Figure 4 shows a field test of the basic system mounted on the car.

Figure 4 Field test of the basic car-mounted detection system, showing the detection of people and cars

Once the basic detection system has been implemented, it is configured for pedestrian detection and alert signalling. If the system detects people in front of the vehicle, standing in the way, the system displays a red "stop person in front" message. In case the pedestrian(s) is/are approaching from the right or left, but not obstructing the road, a corresponding yellow message "caution person on the right" or "caution person on the left" is displayed. In case of pedestrians approaching from both sides, but without obstructing the road, the yellow message "be careful pedestrians on both sides" is displayed".

ISSN-2531-2952

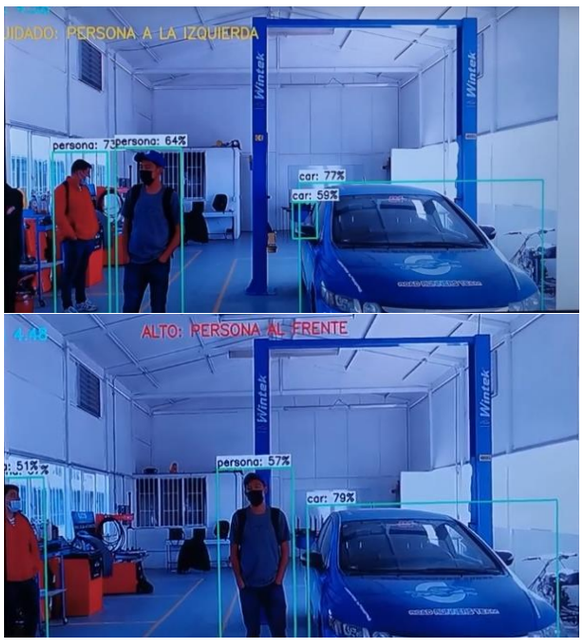

Figure 5 Test of the pedestrian detection system in the laboratory

Results

Once the pedestrian detection system was fully developed and tested in the laboratory, the hardware was mounted on a 2017 Ford Fiesta Sedan, which was then driven outside, encountering pedestrians and vehicles in different situations. The number of objects to be detected simultaneously, the lighting conditions and the speed at which the stimuli occur can be a challenge to overcome. Some images of the field tests are shown in Figure 6.

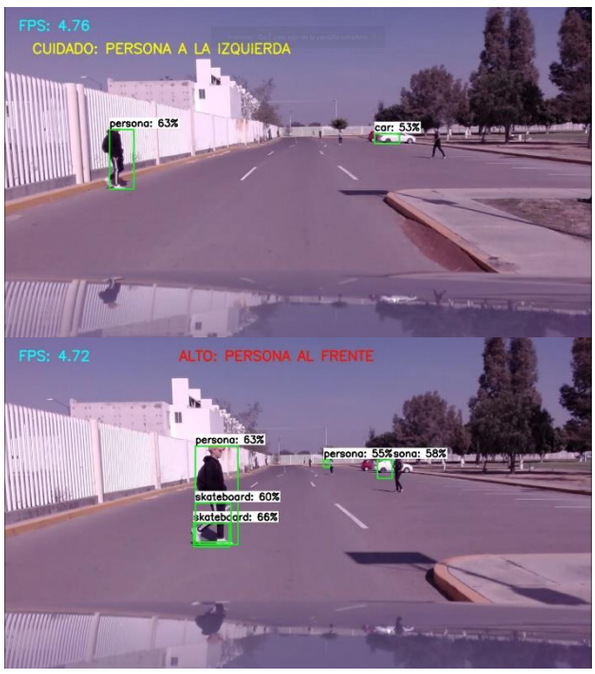

Figure 6 Test of the pedestrian detection system mounted in a car and in a real driving situation

Conclusions

The proposed pedestrian detection system shows promising results, working correctly for each of the vehicle-pedestrian situations that were considered. However, there are issues to improve, such as the number of frames per second that the Raspberry Pi 4 is able to process with the detection system, achieving a maximum of 4, which limits it to low-speed driving situations. On the other hand, false positives and false negatives are present, leading to cases where a pedestrian is mistaken for other objects or simply not detected at all. Although the number of error cases is lower, the occurrence of errors can lead to a serious accident, so improving classification performance is still an area of opportunity.

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ISSN-2531-2952

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ISSN-2531-2952