# Automated Zebra Crossing using Artificial Intelligence

# Noor Azlyn Ab Ghafar<sup>1</sup>, Nur Raihana Sukri<sup>2\*</sup>, and Ninie Farahana Kamarulzaman<sup>3</sup>

<sup>1</sup>Department of Electrical Engineering, Politeknik Sultan Mizan Zainal Abidin, Jalan Paka, 23000 Kuala Dungun, Terengganu, Malaysia.

<sup>2</sup>Department of Mechanical Engineering, Politeknik Ungku Omar, Jalan Raja Musa Mahadi, 31400 Ipoh, Perak, Malaysia.

<sup>3</sup>Department of Mechanical Engineering,
 Politeknik Sultan Azlan Shah,
 35950 Behrang Stesen, Perak, Malaysia.

\*Corresponding Author's Email: nur\_raihana@puo.edu.my

Article History: Received xxxxx; Revised xxxx; Accepted xxxx

©2025 Noor Azlyn Ab Ghafar, Nur Raihana Sukri, and Ninie Farahana Kamarulzaman. Published by Jabatan Pendidikan Politeknik dan Kolej Komuniti. This is an open access article under the CC BY-NC-ND license (<a href="https://creativecommons.org/licenses/by-nc-nd/4.0/">https://creativecommons.org/licenses/by-nc-nd/4.0/</a>).

#### Abstract

Pedestrian safety remains a critical concern, particularly at zebra crossings where accidents often occur due to poor visibility and a lack of driver awareness. This project presents an Automated Zebra Crossing System that integrates Artificial Intelligence (AI) with Raspberry Pi technology to enhance pedestrian safety. The system utilises a webcam and a YOLO-based object detection model to identify pedestrians in real-time. When a pedestrian is detected, the Raspberry Pi triggers a flashing light and buzzer alarm to alert both pedestrians and drivers, ensuring a safer crossing experience. To improve efficiency and sustainability, the system is powered by a 12V lithium-ion battery, recharged via a solar panel, making it energy-efficient and environmentally friendly. The hardware components, including the microprocessor, relay module, and output devices, are enclosed in a waterproof electrical box to withstand various environmental conditions. Additionally, the implementation of the COCO dataset in the YOLO algorithm ensures high detection accuracy, with a confidence score threshold set above 70% to minimise false positives. The results demonstrate that the system effectively detects pedestrians and activates the warning signals in real-time, enhancing road safety. With its high commercial potential, this system can be implemented in industrial areas and later expanded to urban roads with further enhancements. Future improvements include upgrading to more advanced microprocessors, optimising image processing, and increasing public awareness through educational campaigns. Overall, this project contributes to the development of smart transportation systems, promoting safer and more efficient urban mobility.

**Keywords**: Artificial Intelligence, Pedestrian Detection, Raspberry Pi, Smart Transportation System, YOLO Object Detection

#### 1.0 Introduction

Pedestrian safety remains a significant concern in Malaysia, as pedestrians account for the third-highest fatality group in road accidents, following motorcyclists and passenger car occupants. According to the Ministry of Transportation Malaysia (MOT), an average of 542 pedestrian fatalities occurs

annually, translating to approximately 45 deaths per month. Data from the Traffic Investigation and Enforcement Department (JSPT) indicate a downward trend in pedestrian fatalities, with 394 recorded in 2019, 266 in 2020, and 266 in 2021 [1]. Despite this decline, pedestrian-related accidents continue to be a serious issue, highlighting the need for improved safety measures at road crossings.

Traditional zebra crossings and pedestrian traffic lights depend heavily on driver compliance and pedestrian caution. However, such systems are often ineffective, particularly in high-traffic areas where driver inattentiveness and poor visibility pose significant hazards [2]. These challenges are even more pronounced for People with Disabilities (OKU), the elderly, and children, who face mobility, sensory, and reaction-time limitations. Existing systems largely lack intelligent features that dynamically adapt to real-time pedestrian activity, exposing users to avoidable risks.

Several prior studies have proposed sensor-based interventions to improve crossing safety. For instance, Patil et al. [3] developed an Arduino-based system that activates pedestrian lights when motion is detected near a zebra crossing, while Kumar et al. [4] implemented a PIR sensor to alert both pedestrians and vehicles. Although such systems improve visibility, they operate on basic motion detection and do not adapt dynamically to varying pedestrian behaviours or traffic conditions.

Recent research has explored the use of Artificial Intelligence (AI) to enhance detection and decision-making in traffic environments. Kulhandjian et al. [5] introduced an AI-powered pedestrian detection system using thermal imaging and radar to improve visibility in low-light scenarios. El Habchi et al. [6] employed drone-based surveillance to detect crowd movement and pedestrian clustering. While these systems demonstrate technological advancement, they are often hardware-intensive, expensive, or focused on surveillance rather than direct intervention at pedestrian crossings.

However, the majority of current smart crossing systems rely on static sensor-based triggers and lack integration of AI-driven, real-time automation [7, 8]. Many fail to address critical limitations such as driver non-compliance, adaptive response to diverse pedestrian profiles (e.g., OKU), or long-term sustainability through renewable energy sources. While previous studies have proposed sensor-based pedestrian alert systems, few have explored fully automated, AI-driven systems capable of real-time detection and autonomous decision-making. This gap limits the practical deployment of adaptive safety solutions in dynamic urban environments, especially in regions requiring cost-effective and energy-efficient infrastructure.

To bridge this gap, this study proposes an AI-powered Automated Zebra Crossing System that integrates computer vision and sensor fusion for real-time pedestrian detection. The system autonomously triggers visual and auditory alerts for both drivers and pedestrians, significantly improving crossing safety and accessibility, particularly for OKU communities. The

integration of solar energy not only enhances sustainability but also supports long-term deployment in urban and semi-urban settings. This research contributes a novel, cost-effective, and adaptive solution to pedestrian safety challenges by advancing the current state of AI-based traffic control systems. By addressing both technical and social dimensions, including accessibility, real-time decision-making, and energy efficiency, it holds potential for wide-scale adoption in smart city initiatives.

# 2.0 Methodology

This study implements an automated zebra crossing system utilising artificial intelligence (AI) technology integrated with a Raspberry Pi 4B microcomputer. The system uses a webcam and a pre-trained YOLOv5 (You Only Look Once version 5) object detection model to identify pedestrians in real-time. Upon detection, the Raspberry Pi activates a buzzer and flashing light to alert both pedestrians and approaching vehicles, thereby enhancing crossing safety and visibility.

The development process encompasses hardware installation, software integration for real-time object detection, and automated control logic for output responses. The methodology includes four main components: (i) system design and data flow; (ii) hardware configuration and installation; (iii) software programming and AI model setup; and (iv) system logic and pseudocode implementation.

# 2.1 System Architecture and Workflow

The overall system workflow is presented in Figure 1, combining both the project flow and functional block components for clarity and to avoid redundancy. The webcam continuously monitors the crossing zone and sends video input to the Raspberry Pi, which runs the YOLOv5 model for pedestrian detection. Once a "person" is identified, the system triggers two outputs: a flashing light and a buzzer alarm. If no pedestrian is detected, the system reverts to an idle state.

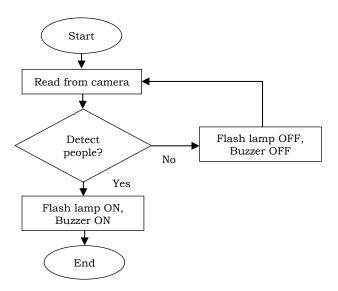


Figure 1: Workflow of automated zebra crossing using AI

The system is composed of the following key components:

- i. Input: Webcam (captures real-time pedestrian movement).
- ii. Processing unit: Raspberry Pi 4B (executes YOLOv5-based pedestrian detection, controls the output).
- iii. Output: Flashing light (alerts pedestrians that the crossing is active) and buzzer alarm (notifies both pedestrians and drivers of crossing activity).

The integration of these components enables a fully automated pedestrian crossing system that enhances safety, accessibility, and efficiency using Albased object detection.

## 2.3 Hardware Configuration

Figure 2 shows the circuit wiring between the microprocessor and connected components. The Raspberry Pi 4B is used due to its better performance and energy efficiency compared to previous models [9]. A 12V DC lithium-ion battery supplies power, supported by a solar panel to ensure uninterrupted, eco-friendly operation. A relay module is used to control the 12V buzzer and flashing light through the Raspberry Pi's GPIO outputs.

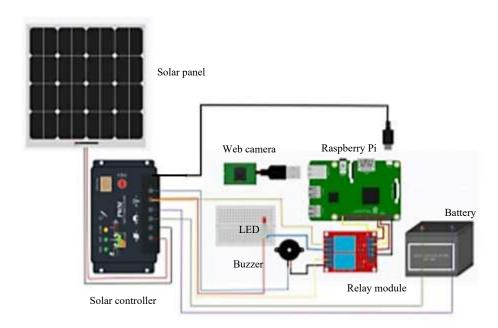


Figure 2: Circuit schematic of Raspberry Pi with output controls via relay

To ensure durability in outdoor conditions, all electronic components are housed in a waterproof enclosure as shown in Figure 3. The box is mounted at a 45-degree tilt, which was determined based on optimal solar irradiance angles for Malaysia's latitude (~4°N), as recommended in photovoltaic deployment studies. This orientation maximises solar energy absorption for battery charging.



Figure 3: Waterproof electrical box for the electrical components

## 2.4 Software Implementation

The software component is implemented in Python and runs on the Raspberry Pi OS. The system uses:

- i. OpenCV An open-source computer vision library for image processing and camera interfacing [10].
- ii. YOLOv5 A real-time object detection model developed by Ultralytics, known for its balance between accuracy and computational efficiency.

YOLO was initially introduced by Redmon et al. [11] and has undergone multiple updates. At the time of this research, YOLOv11 was the latest version, offering enhanced detection speed and accuracy [12]. YOLOv5 was selected in this study due to its compatibility with low-power edge devices like Raspberry Pi. The dataset used for detection is Microsoft COCO (Common Objects in Context), which consists of 80 pre-trained objects as presented in Table 1.

Item No Item No Item No Item No Item Person Sports ball Sandwich 16 Dog 32 48 64 Mouse Bicvcle 49 Orange 17 Horse 33 Kite 65 Remote Car Sheep Baseball bat 50 Broccolo Keyboard Baseball 3 Motorcycle 19 Cow 35 51 Carrot 67 Cell phone glove 20 Airplane Elephant 36 Skateboard 52 Hot dog 68 Microwave 5 53 Bus 21 Bear 37 Surfboard Pizza 69 Oven Tennis Donut 70 Train 22 Zebra 38 54 Toaster racket Truck Giraffe 39 55 Cake 71 Sink Bottle 8 Boat 24 Backpack 40 Wine glass 56 Chair 72 Refrigerator 9 Traffic light Umbrella 41 57 73 Book Cup Couch 42 Fire hydrant Handbag Potted plant 74 10 26 Fork 58 Clock 27 43 Knife 59 Bed 75 11 Stop sign Tie Vase Parking 12 28 Suitcase 44 Spoon 60 Dining table 76 Scissors meter 29 77 13 Bench Frisbee 45 Bowl 61 Toilet Teddy bear 14 Bird 30 46 TV 78 Skis Banana 62 Hair drier 47 79 15 Cat 31 Snowboard 63 Laptop Toothbrush Apple

Table 1: COCO dataset

A detection confidence threshold of 70% was empirically selected after preliminary testing. Thresholds below 70% resulted in false positives (e.g., shadows or background objects being detected as people), while thresholds above 80% occasionally missed actual pedestrians. Thus, 70% were chosen to balance precision and recall, ensuring reliable activation without oversensitivity.

Once a person is detected with ≥70% confidence, the Raspberry Pi triggers the output components via GPIO pins 17 (buzzer) and 26 (flashing light), maintaining the active state for one minute to allow safe crossing. Thus, this output pin is declared before the main program as shown in Figure 4.

```
36 from pathlib import Path
37 import RPi.GPIO as GPIO
38 import time
39
40 LED_PIN =17
41 BUZZER_PIN = 26
42 GPIO.setmode(GPIO.BCM)
43 GPIO.setup(17, GPIO.OUT)
44 GPIO.setup(26, GPIO.OUT)
```

Figure 4: Code for setting the buzzer and flashing light

The program initialises these outputs and follows a conditional activation process. This logic ensures the system only activates upon high-confidence detection of a pedestrian, thereby reducing false activations and improving energy efficiency. The pseudo-code for this operation is presented in Figure 5 below:

```
1. while True:
2.
      read image from web camera
      Import YOLO library
3.
      object detection code
      if (object == "person")
5.
6.
          wait for 2 minutes
7.
          buzzer on for 3 minutes
8.
         flashing lamp on for 3 minutes
9.
      else
10.
         buzzer off
11.
         flashing lamp off
```

Figure 5: Pseudo-code of the program

#### 3.0 Results and Discussion

The AI-powered automated zebra crossing prototype was successfully developed and tested under real-world conditions. The hardware integration of Raspberry Pi 4B, webcam, relay module, buzzer, flashing light, and solar panel demonstrated operational stability. The waterproof casing ensured protection against environmental factors, while the 45-degree solar panel mounting angle ensures optimal sunlight absorption and energy conversion.

#### 3.1 Real-Time Pedestrian Detection Performance

The system was programmed to detect only the "person" class from the Microsoft COCO dataset with a confidence score threshold above 70% to ensure high detection reliability and avoid false positives. During laboratory trials, the system was able to detect pedestrians with this criterion and trigger the buzzer and flashing light accordingly, as shown in Figure 6.

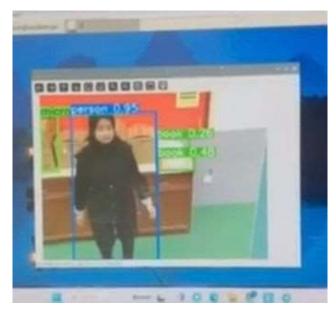


Figure 6: Detection of "person" during lab test session

However, during these lab tests, it was observed that there was a noticeable time lag between detection and system response. This delay is attributed to the limited processing capacity of the Raspberry Pi, which affects real-time image processing speed compared to more powerful hardware. Table 2 presents the recorded detection latency across five trials.

Trial	Detection Rate (s)	Average Detection Rate (s)
First	7.61	
Second	7.38	
Third	7.43	7.54
Forth	8.04	
Fifth	7.25	

Table 2: Detection latency during lab testing

The average detection latency was 7.54 seconds, indicating that while the system successfully identifies pedestrians, the current hardware limits the speed of actuation. For future improvements, the use of mini-PCs or NVIDIA Jetson Nano is recommended to reduce latency and enhance real-time responsiveness.

## 3.2 Power Efficiency and Operational Stability

Solar energy was the primary power source, with a 12V lithium-ion battery

supporting the system. Field measurements showed that a fully charged battery sustained the system for approximately 18 hours, proving it suitable for continuous daily operation without grid dependence.

#### 4.0 Conclusion

This project successfully developed and implemented an AI-powered automated zebra crossing system powered by solar energy. The system detects pedestrians in real time and autonomously activates visual and auditory alerts, enhancing safety at crossings without relying on manual control or grid electricity. The main contribution of this study lies in its integration of real-time object detection using YOLO and sustainable energy through solar power, offering a cost-effective, modular, and autonomous solution for pedestrian safety, particularly in low- to medium-traffic environments such as industrial zones and suburban roads. This system fills a notable gap in existing infrastructure, which often lacks automation or sustainable power sources. Compared to conventional and earlier smart crossing systems, this prototype operates more intelligently and independently, distinguishing itself through its AI-based detection, renewable energy use, and adaptability to underserved areas. To further improve system performance, future work should focus on reducing detection latency, improving accuracy in crowded or low-visibility conditions, and enhancing hardware resilience in outdoor environments. Upgrading to more powerful processors like Jetson Nano and using weatherproof, high-resolution cameras is recommended. Quantitative targets such as reducing latency below 3 seconds and achieving over 95% detection accuracy under various lighting conditions should guide future iterations. In conclusion, this research presents a practical and scalable contribution to smart transportation initiatives, addressing real-world challenges in pedestrian safety with a sustainable and intelligent solution.

### Acknowledgement

The authors extend their sincere gratitude to all individuals and organisations for their invaluable support, guidance, and contributions toward the successful completion of this project.

#### **Author Contributions**

**Noor Azlyn Ab Ghafar**: Data Curation, Software, Hardware, Formal Analysis, Visualisation; **Nur Raihana Sukri**: Conceptualisation, Supervision, Writing-Review & Editing; **Ninie Farahana Kamarulzaman**: Investigation, Validation, Writing-Original Draft.

#### **Conflicts of Interest**

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have reviewed and approved the manuscript, consent to its submission, and declare that there are no conflicts of interest.

#### References

- [1] N.A. Malik. (2022). "INFOTRAFIK: Risiko Bahaya pejalan kaki," [Online]. Available: https://www.mkn.gov.my/web/ms/2022/03/08/infotrafikrisiko-bahaya-pejalan-kaki/[Accessed: 12-Jun-2025].
- [2] B. E. Zakka, M. M. Mohammed, and I. H. Aminu, "Intelligent zebra crossing using motion detection," *International Journal of Advanced Research in Innovative Ideas in Education*, vol. 9, no. 4, pp. 2910–2916, 2023.
- [3] K. T. Patil, D. A. Salunkhe, and S. T. Chaus, "Automatic zebra crossing using Raspberry Pi," *International Journal of Innovative Science and Research Technology*, vol. 9, no. 6, pp. 729–736, Jun. 2024.
- [4] S. Kumar, R. K. Srivastava, M. Singh, and A. Pandey, "Wireless sensor network-based real-time pedestrian detection and classification for intelligent transportation system," *International Journal of Mathematics in Engineering and Management Sciences*, vol. 8, no. 2, pp. 194–207, 2023.
- [5] H. Kulhandjian, A. Moghaddam, and M. Thakur, "AI-based pedestrian detection and avoidance at night using multiple sensors," *Journal of Sensor and Actuator Networks*, vol. 13, no. 3, pp. 34–50, 2024.
- [6] A. El Habchi, H. Yousfi, and R. Ezzati, "Social distance monitoring using YOLOv4 on aerial drone images," in *E3S Web of Conferences*, vol. 351, p. 01035, 2022, doi: 10.1051/e3sconf/202235101035.
- [7] A. Mohanty, A. G. Mohapatra, and S. K. Mohanty, "Real-time traffic monitoring with AI in smart cities," in *Internet of Vehicles and Computer Vision Solutions for Smart City Transformations*, Cham, Switzerland: Springer Nature, 2025, pp. 135–165, doi: 10.1007/978-3-031-XXXX-X\_8.
- [8] A. Ait Ouallane, A. Bahnasse, A. Bakali, and M. Talea, "Overview of road traffic management solutions based on IoT and AI," *Procedia Computer Science*, vol. 198, pp. 518–523, 2022, doi: 10.1016/j.procs.2021.12.345.
- [9] E. Gamess and S. Hernandez, "Performance evaluation of different Raspberry Pi models for a broad spectrum of interests," *International Journal of Advanced Computer Science and Applications*, vol. 13, no. 2, pp. 819–829, 2022, doi: 10.14569/IJACSA.2022.01302102.
- [10] K. Selvaraj, A. Ravi, and M. Thangavelu, "Raspberry Pi-based automatic door control system," in *Proceedings of the 3rd International Conference on Signal Processing and Communication*, 2021, pp. 652–656, doi: 10.1109/ICSPC.2021.9545678.
- [11] J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, "You only look once: Unified, real-time object detection," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2016, pp. 779–788, doi: 10.1109/CVPR.2016.91.
- [12] P. Jiang, Q. Wang, and J. Han, "A review of YOLO algorithm developments," *Procedia Computer Science*, vol. 199, pp. 1066–1073, 2022, doi: 10.1016/j.procs.2022.01.345.