Intelligent Zebra Crossing Using Motion Detection

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Abstract

The movement of pedestrians is challenging to control due to varying levels of ability and physical factors such as age, gender, and endurance. The increase in urban population density and traffic infrastructure has made zebra crossings hazardous to pedestrians, resulting in many deaths. At the Federal Polytechnic Bauchi, most zebra crossings have faded out, putting pedestrians at risk since vehicle drivers tend to overrun the marks. Vehicle drivers often disregard the zebra crossing system, and pedestrians are hit while crossing the road. To address these challenges, an intelligent zebra crossing system was developed. It is an Arduino-based prototype that automates pedestrian crossing using a pedestrian light system triggered by ultrasonic sensors. When a pedestrian enters the detection zone, the sensor triggers a red signal to vehicular traffic and a green signal to pedestrians after the road lane is bracketed. This system has been tested successfully, and its implementation will improve pedestrian safety and reduce road accidents involving pedestrians

.**Keywords:** *Motion, Pedestrian, Zebra Crossing, Traffic*

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1 INTRODUCTION

According to the World Health Organization (WHO, 2018), road traffic injuries (RTIs) are among the top 10 causes of death worldwide, with a greater negative impact on those aged 5 to 29 years (Passmore et al., 2019). While the number of traffic deaths decreased in 48 middle- and high-income countries between 2013 and 2016, pedestrians in low- and middle-income nations, particularly in the African, Eastern Mediterranean, and Western Pacific areas, still experience a disproportionate amount of stress from vehicle traffic (Namatovu et al., 2022). Pedestrians in the African continent are responsible for 38% of all fatal traffic accidents, compared to 22% globally. The WHO estimates that each year, 1.35 million people die and up to 50 million more suffer non-fatal injuries as a result of traffic accidents, with schoolchildren and the elderly at a higher risk of pedestrian accidents, and children as young as 11 having to navigate the task of crossing the road (Muntasir et al., 2018). The current zebra crossing system is plagued by a lack of respect from drivers who ignore the legal requirement to stop at zebra crossings, where pedestrians have the right-of-way (Dow et al., 2020). To address this issue and prevent fatalities, it is essential to control vehicle speed and horn usage. The highway department has implemented the Zebra line, a critical traffic sign that provides a safe crossing for pedestrians at crossroads (Sajan & King, 2021). This study seeks to develop and deploy an intelligent zebra crossing system that utilizes motion detection to detect the presence of people seeking to cross the road.

1.1 THE CONCEPT OF ZEBRA CROSSING

Pedestrians refer to individuals traveling on foot or with small wheels, including wheelchair users, roller skaters, skateboarders, and scooter riders (Liu et al., 2017). Pedestrians are crucial for urban activities such as employment, shopping, sightseeing, and other uses (Aqmal et al., 2019a; Muntasir et al., 2018). To ensure pedestrian safety when crossing roads, zebra crossings are installed in towns and residential areas. These crossings are marked by transverse white lines across the road, either at junctions or in the middle of blocks (Alvarez et al., 2018). However, speed limiters may not protect pedestrians from overconfidence when crossing the road, leading to dangerous situations (Meem et al., 2021). To manage traffic flow in cities, it is necessary to incorporate innovative technologies, driven by user expectations and traffic regulation complexity (Saber et al., 2020; Martinez et al., 2018; Lu et al., 2020). Sensor feedback signals serve as the foundation for urban traffic optimization and management, and various sensors are used for different categories of traffic participants (Federal Highway Administration, 2021). Although the use of autonomous artificial intelligence-driven decision algorithms for video surveillance systems is being actively researched, numerous solutions based on different sensors are currently in use (Kato et al., 2017; Xiao et al., 2021).

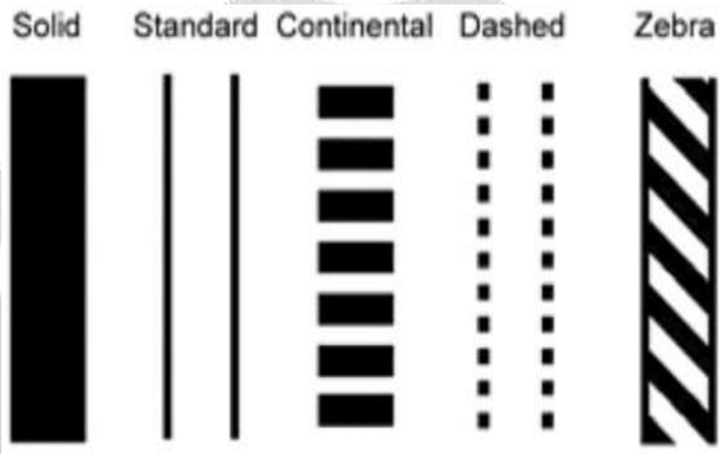

Figure 1: Crosswalk marking patterns Crossings (Source: (Meem et al., 2021)

2 RELATED WORK

Various sensors and methods are being investigated for the detection of pedestrians among traffic participants, as noted by Nimac et al. (2022). Computer vision technology is a popular tool for pedestrian detection, with significant advancements made in recent years (Cao et al., 2021). Muntasir et al. (2018) developed a fast and reliable algorithm for locating a pedestrian crossing using an image captured by a single camera. The algorithm involves three steps: segmentation of the image based on bipolarity, selection of crossing candidates based on area, and identification of the crossing using projective invariants extracted from the candidate area using Fisher criterion. On the other hand, Cheng & Zhang (2017) utilized an integral method based on horizontal projection to detect zebra crossings.

Several studies (Saad et al., 2020; Liu et al., 2017; Pau et al., 2018) have presented systems that detect and analyze pedestrian crossings in various environments and lighting conditions. These systems automate the detection of contaminated or damaged crossings. Additionally, Raul et al., (2018) proposed a method to predict the future trajectory, posture, and intention of pedestrians. This method uses the Gaussian process dynamics model (B-GPDMs) to extract key joints or points of pedestrians and infer their trajectory and intention. The accuracy of this method's recognition can increase to 80%.

Researchers have explored various methods for pedestrian intention recognition, such as a hidden Markov model-based approach, as discussed in studies by Raul et al. (2018; 2017), which used crucial body positions and achieved an 80% accuracy in recognizing pedestrian intentions 125 milliseconds after movement began. Other studies, such as Fang et al. (2017; 2019), focused on extracting feature vectors of human body parts to identify intentions with an accuracy of 93%. Hasan et al. (2022) developed an automated personalized agent to detect threats and alert pedestrians in urban settings, while Variimidis et al. (2018) achieved 72% and 85% accuracy in head orientation estimation and motion detection, respectively, to determine if pedestrians are about to cross the street. Rasouli et al. (2017) used AlexNet to extract features from pedestrian movement and the environment and fed them into a linear SVM to generate a feature matrix for predicting whether pedestrians will cross the roadway.

In their study, Fascioli et al. (2020) explored the utilization of stereo vision to enhance road user safety by detecting pedestrians. The method involved comparing two bird's-eye views of the crossing to identify objects rising above the road plane. Völz et al. (2018) proposed a technique for predicting pedestrian intention by integrating a pedestrian motion tracking algorithm with a data-driven approach, in order to improve the model's generalizability. Camara et al. (2019) introduced an intention heuristic model that uses relative position, vehicle trajectory, and pedestrian trajectory as input parameters to predict the crossing intention of pedestrians with 96% accuracy using the Daimler standard pedestrian data collection. Meanwhile, the enhanced naive Bayesian technique proposed by Zhao et al. (2019) was successful in detecting pedestrian intention 0.5 seconds before the pedestrian crossing.

Aqmal et al. (2019) developed and tested a modern and user-friendly prototype for a zebra crossing at Politeknik Ungku Omar and Sekolah Menengah Kebangsaan Raja Chulan Ipoh. The aim was to reduce congestion and the risk of accidents, especially during peak hours. Skovierov et al. (2018) used Bayesian networks to identify pedestrian intention by gathering position, speed, and direction data from all pedestrian traffic participants. Zhao et al. (2018) used lidar to collect speed, location, and direction data of pedestrians and employed a deep auto-encoder-artificial neural network (DA-ANN) to accurately determine pedestrian intention with 95% accuracy.

Alvarez et al. (2018) developed an automatic camera calibration system for Intelligent Transportation Systems using monocular vision. They proposed a method for camera calibration using a zebra crossing as a common element of urban traffic infrastructures, without prior knowledge of the scene. In another study, Muntasir et al. (2018) proposed a low-cost and easy-to-use system based on Arduino UNO to measure the parameters of an automated zebra crossing system. Xie et al. (2018) used random parameter and effect models to address variations in explanatory variables among pedestrians and unobserved heterogeneity across sites. They employed a binary logit model to identify potential factors affecting the likelihood of pedestrian jaywalking, with the random parameter model showing the best fit. Dow et al. (2020) suggested a real-time pedestrian recognition system that utilizes a deep learning classifier and zebra-crossing recognition methods to increase intersection safety and reduce collisions. To enhance fault tolerance and maintain detection accuracy, they employed a dual-camera approach.

Various researchers have proposed innovative solutions to improve pedestrian safety and detection. Prasad et al. (2021) suggested installing automatic barriers at zebra crossings to reduce accidents. The barriers rise automatically when pedestrians are crossing and lower when vehicles are moving. Kim (2020) proposed a YOLO-Based Simultaneous Target Detection method, which shows superior performance in detection and classification compared to traditional approaches. Yuan and Qu (2017) proposed a method based on a convolutional neural network and Tensor Flow to detect specific sensitive characters. This method provides better recognition accuracy and greater robustness in challenging environments. Otkovi et al. (2019) created two models, one based on multiple linear regression and the other on neural networks, to predict the speed of children crossing signalized pedestrian crosswalks. Both models use children's traits and movements as well as transportation infrastructure parameters. The models were tested using data collected from similar pedestrian crosswalks in Rijeka, Croatia and Enna, Italy. The results show that the neural network model, developed for Osijek, can be applied with sufficient reliability to the other two cities, whereas the multiple linear regression models can only be applied with a fair amount of confidence to Rijeka.

Olszewski et al. (2019) used video processing to identify the motion trajectories of automobiles and pedestrians and calculated several characteristics to represent the interactions between them, including speed, post-encroachment time, and separation between participants. Chang (2020) developed an Assistive System for Visually Impaired Pedestrian Safety at Zebra Crossings based on Artificial Intelligence and Edge Computing, which alerts visually impaired pedestrians as they approach a zebra crossing, providing information on the traffic light status and other circumstances. Wu (2019) proposed a Block-Based Hough Transform to recognize zebra crossings in natural scene images and determine their location and direction. Meem et al. (2021) presented a method for zebra crossing detection and recognition that uses an SVM classifier and image processing techniques like adaptive histogram equalization, flood fill operation, and Hough transforms to identify and locate the crossing region.

3 METHODOLOGY

3.1 Problems of the existing system

3.2 After analyzing the system, the following observations were made about the current state: Pedestrians tend to disregard the right of way on zebra crossings, resulting in potentially hazardous situations. Pedestrians are frequently hit by vehicles on zebra crossings, especially during peak hours when vehicular traffic is heavier. Additionally, many drivers tend to blame pedestrians for incidents on zebra crossings, while pedestrians accuse motorists of marginalizing them.

3.3 Analysis of the proposed system

The proposed system aims to address the issues observed in the existing system by introducing an intelligent zebra crossing. This system will be automated and controlled by a traffic and pedestrian light system triggered by ultrasonic sensors. It will be an Arduino-based prototype supported by a set of traffic lights that will be controlled by an ultrasonic sensor. When a pedestrian is detected in the detection zone, the sensor will trigger a red signal to vehicular traffic and a green signal to pedestrians. An amber signal will go first and blink three times, serving as a warning to motorists to stop and give way to pedestrians as the red signal progresses. The zebra crossing will also have a barrier that comes up to prevent vehicles from disobeying traffic lights and provide safety to pedestrians. Additionally, a countdown of ten seconds will be provided, and the red signal will go on for pedestrians. As the pedestrian red signal goes on, the green signal will open up for motorists, giving them the right of way. The system will repeat its loop whenever a pedestrian is detected by the ultrasonic sensor. With these features, the proposed system aims to improve pedestrian safety and ensure that both pedestrians and motorists follow traffic rules at zebra crossings.

3.4 Features of the Proposed System

The proposed system will be using traffic lights to control pedestrians and vehicles, will use Arduino Unimicro-controller *to connect and distribute the various inputs gotten and also so supply power supply*, and use LED to indicate either to stop or give way to the users of the vehicle, use an ultrasonic sensor to sense pedestrian, adopts servo motor for barrier control, uses Resistor for voltage resistance, and was constructed by interfacing each required component together.

3.5 System Design

Figure. 2 gives pictorial details of the system design. the system senses when a pedestrian or a vehicle is in view, through an ultrasonic sensor and sends a signal to the Arduino microcontroller. The Arduino microcontroller receives and identifies the signal and in return gives a command to traffic lights or the barriers to respond accordingly based on the signal received from the sensor.

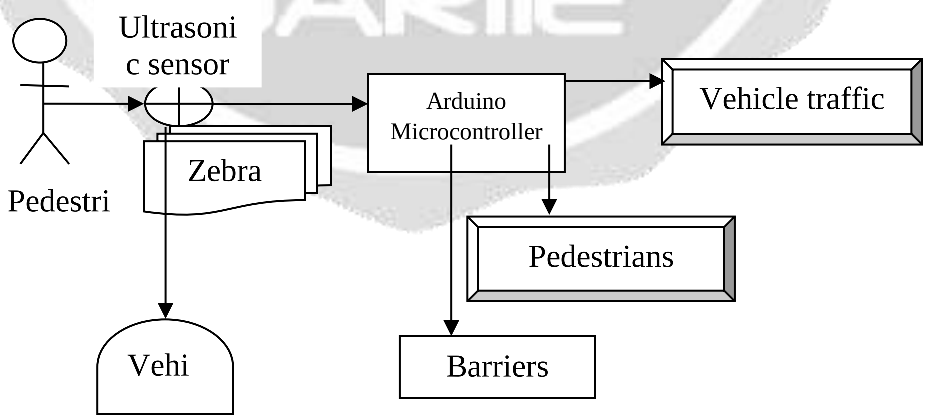

Figure 2: System design

3.6 How the proposed system works

The proposed embedded system was constructed by interfacing each required component together. The system starts by powering the Arduino microcontroller to establish a connection with the sensor, traffic, and barrier. It then checks the pedestrians if Yes the vehicle traffic lights trigger red and a barrier drops to protect the pedestrian and green for the pedestrian to pass while if No the traffic light triggers red for the pedestrians and green for the vehicle. The Arduino sensor senses the pedestrians and vehicles in the developed system that was developed, servo motor controls the barrier that blocks the road and prevents the vehicle from going against the traffic lights and the law. Led was used to indicate commanded light which is green to pass, yellow to get ready, and red to stop. The sensor senses and send a signal to the Arduino controller and the Arduino will give the command to the traffic light and barrier to assign the right of way based on the sensor. The system senses pedestrians and vehicles through the ultrasonic sensor and sends a signal to the Arduino microcontroller. The Arduino microcontroller received the signal and identifier signal and give a command to traffic lights and barrier to perform an action based on the signal received from the sensor.

4 RESULT

Based on the input, process, and output of this research work, the figure below displays the different test cases obtained from the results of the proposed system. The input involves the recruitment of participants based on multiple decision-making criteria. The process includes the use of the proposed system to gather data and generate results. The output shows the different test cases obtained from the results of the system, which can be analyzed and evaluated to determine the effectiveness of the proposed system. The figure provides a visual representation of the different test cases and how they relate to the input and process of the research work.

Figure 3: Test Cases

Test case1: This illustrates the resulting output of the developed system when a Car is detected in one lane and pedestrians are stopped.
Test case 2: Illustrates the resulting output of the developed system when Pedestrians are detected on one side and pedestrian cars are stopped.
Test case three: Illustrates the resulting output of the developed system when a Car is detected in both lanes and pedestrians are stopped.
Test case four: Illustrates the resulting output of the developed system when Pedestrians are detected on both sides and pedestrian cars are stopped.

4.1 Discussion of results

The developed system was tested successfully and the results of each test are discussed thus; Test Case one was successful: using the developed system, the car was detected in one lane of the route, and the right of way was given to the car, whereas pedestrians were being stopped. Test Case two was successful: using the developed system, a pedestrian was detected on one side of the route, and the right of way was given to the pedestrian, whereas cars were being stopped. Test Case three was successful: using the developed system, a car was detected in both lanes of the route, and the right of way was given to the cars, whereas pedestrians were being stopped. Finally, test case four was successful: using the developed system, pedestrians were detected on both sides of the route, and the right of way was given to the pedestrians, whereas cars were being stopped.

Hence, from the above successful test cases, the developed system was able to function properly by the objectives of the research work. With this, the safety and confidence of the pedestrian will be improved and road accidents concerning a pedestrian will drastically reduce to the minimum.

5 CONCLUSION

In summary, the proposed method for zebra crossing detection and recognition is based on sensing methods that do not require any prior information. The system is designed to ensure equal and fair allocation of right-of-way while ensuring safe and orderly traffic flow and pedestrian protection. The system will significantly impact the free flow of traffic by assigning the right-of-way to a certain traffic movement. This infrastructure will ensure pedestrian safety at busy zebra crossing locations that receive little regard from drivers. Future upgrades to the system could include electromagnetic or radar detectors that gauge the speed of approaching cars, emit red signals to enforce speed limits, and provide countdown timers for both drivers and pedestrians. Overall, the proposed system has the potential to improve pedestrian safety and traffic flow at zebra crossings.

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