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Real-Time Vision-Based & Optimized Pedestrian Crossing Control System

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Abstract: As per the National Council for Road Safety, more than 900 fatalities have been reported due to vehicle collisions on or near pedestrian crossings during the past 10 years within Sri Lanka. However, only minimal research has been carried out so far to improve the safety conditions of pedestrians. This research focuses on developing a system utilizing image processing to obtain the real-time data of a group of pedestrians at crosswalks and determining of an optimal time frame for a certain group of pedestrians to cross the road at a given time period. This study concludes on the necessary requirements to optimize the timing of the existing push-button based signaling system. A mobile based app is also developed to assist drivers to be incorporated with the proposed signaling system to enhance the end-effect. Extensive trials prove that the proposed system would ensure pedestrian safety and minimize or even prevent reckless road collisions within crosswalks.

Keywords: Pedestrian Safety, Image Processing, Road Traffic, Pedestrian group density, Vehicle queue density.

Introduction

Different people may follow diversified modes for transportation, however at one time or another everyone may act as a pedestrian. A pedestrian crossing or a crosswalk is a pedestrian's path of travel across the motorist's path of travel, where the pedestrian should ideally be given the priority. At pedestrian crosswalks, pedestrians have the right of access as in some countries [6] pedestrians are given right of way as soon as they step on the crossing. However, pedestrians will have to start crossing the road to get the right to access [1] in some regions.

Pedestrian crosswalks are either established at a junction, called intersection crossings, or just on the road where there are necessarily no intersections but are needed due to the high vehicle density, speed, and width of the road, known as midblock crossings. Pedestrian crossings can be classified into two categories as signalized crossings and un-signalized crossings. Signalized crossings are with control devices that clearly separate pedestrians from vehicles in the area of the crossing. Un-signalized crossings are the type that generally offer no assistance to pedestrians.

Pedestrians are the mostly vulnerable and slowest type of traffic or movement on the road. Marked crossings can provide a sense of false security which makes pedestrians enter without assessing the traffic situation. Pedestrians also tend to presume vehicles would stop at any instance which is obviously may not be the case. The fatalities that occurred on or near pedestrian crossings in Sri Lanka during last 10 years are presented in the table 1 below:

Table 1. Pedestrian Fatalities at Pedestrian Crossings in Sri Lanka over the last decade according to Colombo Municipal Council (CMC)

Year	Number of Fatalities at pedestrian crossings
2008	71
2009	94
2010	120
2011	110
2012	110
2013	112
2014	119
2015	122
2016	130
2017	120
2018	117

It can be observed that pedestrian collisions on crosswalks are in fact at a very serious state and a delicate issue that needs to be urgently deemed.

The main risks to pedestrians are well recognized, and they include issues related to a broad range of factors such as driver behavior, specifically concerning speeding as well as drinking and driving; lack of infrastructure in terms of dedicated facilities for pedestrians such as sidewalks, crossings, and raised medians; and vehicle design in terms of solid vehicle fronts that are not forgiving to pedestrians should they be struck.

Whether a certain crosswalk is signalized or not doesn't mean it is safe as most drivers don't necessarily acknowledge the presence of a crosswalk on the road and most pedestrians don't acknowledge the vehicle density and their speeds when crossing the road in Sri Lanka. Pedestrian crosswalks are an important element in road networks and there are hundreds of different crosswalks all over Sri Lanka. This research was based on a signalized midblock crossing situated in Galle Road; Belek Kade Junction, Ratmalana.

The rest of the paper is presented as follows: Section II provides an overview of related prior research, Section III gives an insight into the pedestrian behavior on crosswalks, Section IV includes the proposed model, design and methodology of the system, Section V provides performance analysis with the discussion. Section VI concludes and finally with section VII predicts further research possibilities.

Related Work

The number of researches has been carried out in this regard; however, only limited attention has been directed for the problem of optimization of the existing set up of the crosswalk.

[3], has proposed a coordination control model for signalized midblock pedestrian crossing and adjacent intersections to enhance the efficiency of the arterial where common cycle length model was developed based on the original optimal cycle of pedestrian crossings and intersections. The work in [4] has carried out on the factors causing the violating behaviors of pedestrians at crosswalks. The researchers show that the ineffectiveness of the pedestrian crossing signal coordination time cycles as the main factor for violating the behavior of pedestrians at crossings. In [5] two approaches have been compared to predict collisions. 1. Model-Based Approach, 2. Learning-Based Approach and suggests that a deep reinforcement learning as the best approach as it is faster and inexpensive for predicting collisions with the highest level of accuracy [5].

Pedestrian Behaviour

According to the State Development & Construction Cooperation (SD&CC) in Sri Lanka, the typical speed of a pedestrian in Sri Lanka is about 1.66 m/s. That is, the pedestrian can walk nearly 1.7 m within one second. Table 2 presents the values for different categories of pedestrians.

Table 2. General crossing speeds of pedestrians with and without walking difficulty

Average	Speed (m/s)	Standard Deviation (m/s)	15th percentile (m/s)	50th percentile (m/s)	85th percentile (m/s)
Pedestrians with walking difficulty	1.35	0.08	1.14	1.29	1.63
Pedestrians without walking difficulty	1.70	0.15	1.31	1.60	2.04
All pedestrians	1.63	0.15	1.24	1.56	1.96

Belek Kade crosswalk is of 20 meters in length and is allocated with a fixed timer of 20 seconds for pedestrians to cross. Our research objective was to provide an optimal period depending on the different types of pedestrians waiting to cross the road.

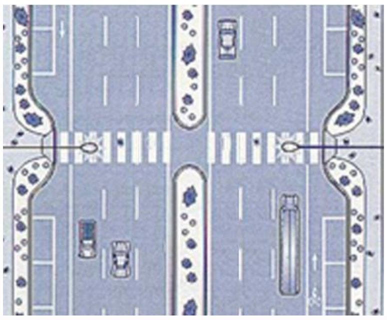

Fig. 1. Top View of the chosen crossing at Belek Kade, Ratmalana

The Belek Kade crossing encounters with three vehicle lanes from each side as shown in the above Fig. 1.

Methodology

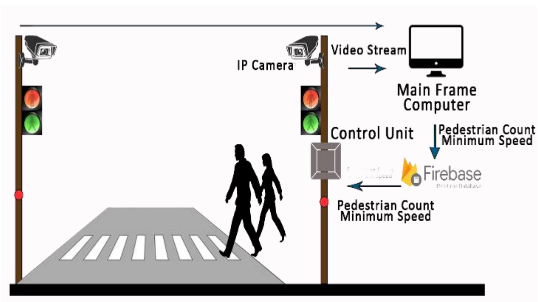

Fig. 2. Research Design

A. *IMAGE PROCESSING ALGORITHM*

This study was mainly based on the use of image processing where a live feed of pedestrians waiting to cross the road at a crosswalk was obtained. The setup is depicted in Fig. 2 above. A pedestrian is identified by a "bounding box" through the image processing algorithm. If more than one pedestrian is present, then each of them was identified by individual bounding boxes to obtain their unique speeds respectively. This real-time data was stored on an online database (Firebase Realtime Database) while being updated every 2 seconds onto a mainframe computer.

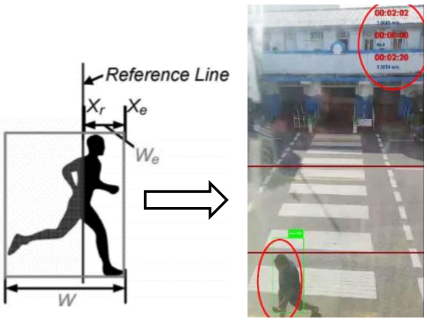

Fig. 3. Bounding Box Notation for the pedestrian crossing event

In reference to Fig. 3, Xe is the X-axis value of the right edge of the pedestrian's bounding box, Xr is the X-axis value of a vertical reference line and W is the horizontal width of the bounding box.

Depending on the pedestrian count, the average speed was obtained which is the minimum speed (i.e. the slowest pedestrian).

Fig. 4. Various cases of cropped training samples, with different entering angles/directions

B. *SIGNALING MODEL*

The existing time allocation system follows a method, that, for any pedestrian crosswalk, the crossing width is measured in meters where one meter is equivalent to one second. Hence, most of the crosswalks in Galle Road are allotted with a crossing time of 20 seconds. We were constrained to not increase the allocated time interval for crossing by traffic controlling authorities as it would add an extra burden on vehicular traffic. Therefore, the upper limit of crossing time was 20 seconds. Data was collected at the Belek Kade Junction crossing where groups consisting of less than 6 people were randomly observed at peak (12:00 p.m. -2:00 p.m.) and off-peak times (10:00 a.m. – 11:00 a.m.) where a maximum of 18 seconds were taken by the pedestrians to finish their crossings. Based on this observation, a simple model was designed to control pedestrian crossing time based on the pedestrian densities at the crossings.

Thus, a simple logic was established that if the number of pedestrians is less than or equal to 5, the crossing time should be 18 seconds and if the number of pedestrians is more than 5, the crossing time should be changed to 20 seconds.

Graphs in figure 4 and figure 5 below indicate a normal distribution obtained by plotting the probability of occurrence of the duration of time vs. time in seconds.

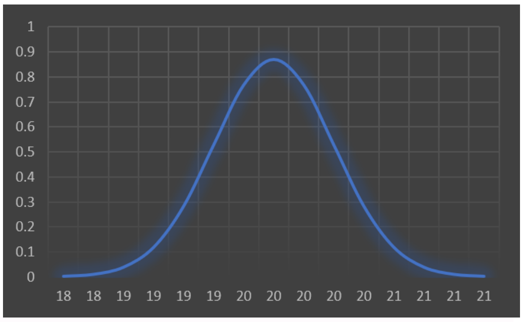

Fig. 5. Graph shows the variation when the no. of pedestrians waiting to cross is 6 or more

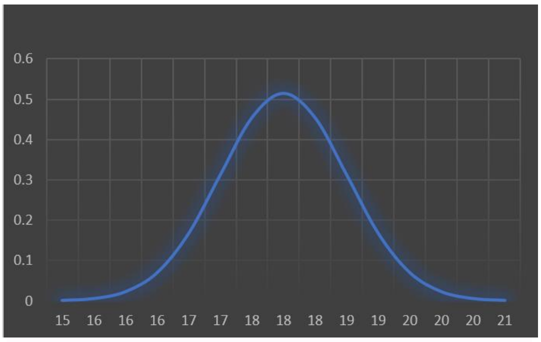

Fig. 6. Graph shows the variation when the no. of pedestrians waiting to cross is less than 6

C. CONTROL UNIT

In order to control the system, a microcontroller (Raspberry Pi 3B+) was utilized along with the controlling PLC. When a pedestrian comes into contact with the push button, after allowing 60 seconds in the green phase of the vehicle cycle, a 15 second timer begins inside the microcontroller. In the last 5 seconds of that, the real time pedestrian data uploaded to the database via the image processing system and gets downloaded by the microcontroller. According to the downloaded data, pedestrian crossing time was calculated and the calculated time was sent to the PLC. In the last 2 seconds of the timer, a Wi-Fi SSID begins to broadcast to alert the driver of a crosswalk ahead via the mobile app which is also made to emit from the microcontroller.

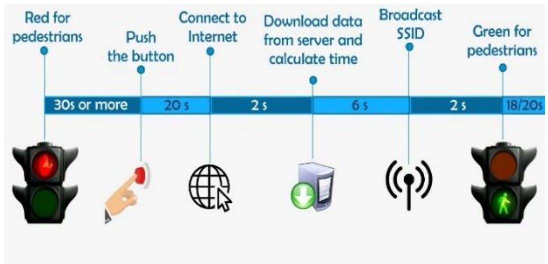

Fig. 7. Timing Cycle

D. DEVELOPMENT OF MOBILE APPLICATION

A mobile application was designed for the purpose of alerting the motorists of a crosswalk ahead. This background running app was developed using Android Studio 3.1.3 and does not require any network connection in order to be activated.

The detection process happens via a SSID emitted from the Raspberry Pi module where the app was rendered to identify this SSID as a Wi-Fi hotspot via the driver's mobile phone. Once this detection occurs, a sequence of continuous "beep" sounds was set to go off acknowledging the motorist of a possible crossing ahead.

The objective of creating an app was to make sure the driver slows down and eventually stops before a certain crosswalk. The app also aids as an additional tool for the conservative signaling system.

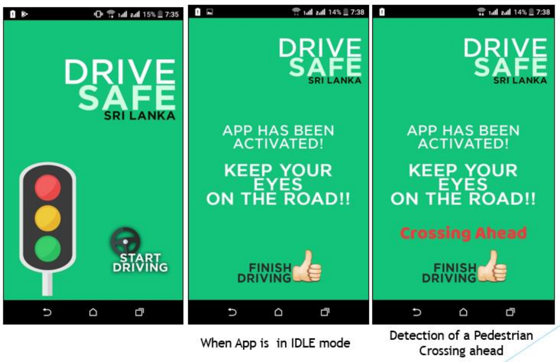

Fig. 8. "Drive Safe" Application Interface

E. ANYLOGIC SIMULATION MODEL

AnyLogic is a multimethod simulation modeling tool developed by The AnyLogic Company where it supports agent-based, discrete event, and system dynamics simulation methodologies.

AnyLogic includes a graphical modeling language and allows the user to extend simulation models with JAVA code through custom model extensions.

It can specifically be used to simulate pedestrian dynamics and road traffic situations.

Results

To show the applicability of the suggested model, the following results were obtained after simulating the existing pedestrian light controlling model and the suggested model using the AnyLogic simulation software. This simulation was based on the extensive data obtained at the Belek Kade Junction pedestrian crossing as the experimental setup.

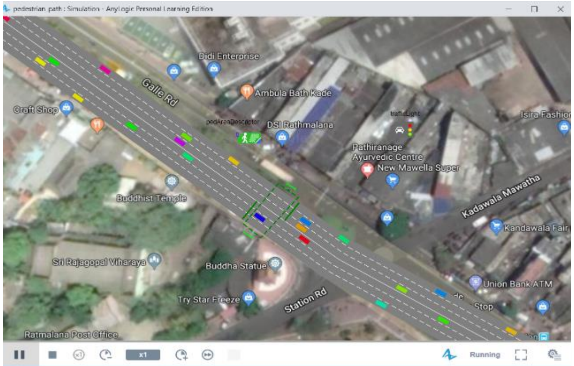

Fig.9. Vehicle queue density obtained using AnyLogic Simulation

These results show that the vehicle queue density (y-axis) during the observed hours of the day (x-axis) for the current model and the suggested model.

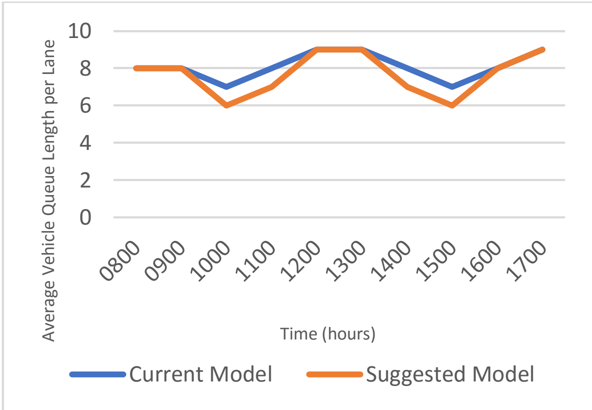

Fig. 10. Vehicle queue density in each lane from Colombo to Moratuwa

Thus, from Colombo to Moratuwa lane, a slight reduction in queue length was observed during certain off-peak hours from 9.30 am to 11.45 am and from 1.30 pm until 3.50 pm.

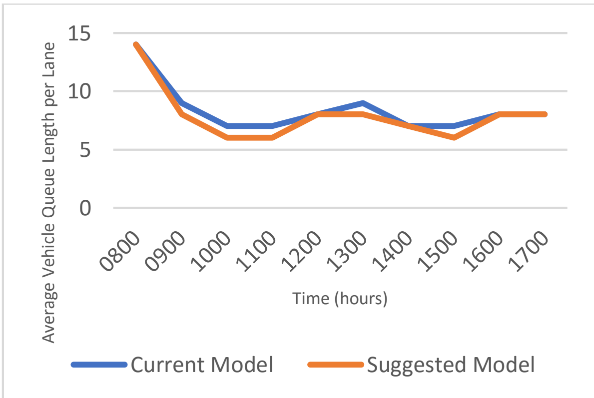

Fig. 11. Vehicle queue density in each lane from Moratuwa to Colombo

From Moratuwa to Colombo lane, a slight reduction in queue length was observed at some off-peak hours from 9.00 am to 11.30 am, from 12.00 pm to 1.30 pm and again from 14.15 pm until 16.00 pm.

Conclusion

The analysis of vehicle queue density reveals that vehicle traffic can, in fact, be reduced during certain off-peak hours by utilizing the proposed model. The pedestrian safety issues on the road can be mitigated using a driver alarming system as it assists in directing the driver's concentration more towards the road and pedestrians, during the approach. Pedestrian collisions like other road accidents should not be accepted as inevitable because they are, in fact, both unpredictable however avoidable if correct preventative measures are taken. Hence, it can be concluded that this research is indeed an area of great opportunity to be explored further and results will provide greater efficiency, safer roads for pedestrians as well as for vehicle users.

Future Works

The work is in progress to extend the utility of our research under the following aspects:

a) The existing app is enhanced to aid for differently abled pedestrians with severe visual impairments, in order to assist them in crossing the road more safely and without any assistance.
b) Development of an augmented reality application to display across a certain alert patterns to direct the driver's attention.

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