Pedestrian Crossing Safety System at Traffic Lights based on Decision Tree Algorithm

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***Abstract*—Pedestrians are one of the street users who have the right to get priority on security. Highway users such as vehicle drivers sometimes violate the traffic lights that is endanger pedestrians and make pedestrians feel insecure when crossing the street. Based on this problem, a tool is designed to provide a warning for the drivers or riders violating the traffic lights and prevent traffic accident by spraying water. The system is able to detect traffic violation based on changes in the value of the vehicle position on the stop line obtained from the Ultrasonic HC-SR04 sensor. When a violation is detected, a decision tree algorithm turns on the pump to spray water to the traffic violators as a deterrent effect. The results show that the vehicle located closest to the sensor has 94% precision, 88% recall and 85% accuracy, the vehicle located in the middle has 73% precision, 100% recall, and 75% accuracy, and the vehicle located furthest to the sensor has 75% precision, 100% recall and 80% accuracy.**

Keywords*—*Pedestrian safety; decision tree algorithm: traffic light; spraying water

I. Introduction

The pedestrians have the right to get the most priority security and comfort on the street. Motorcycle and car users sometimes endanger pedestrians by violating the traffic lights. A safety system to protect the pedestrians from those who violate the traffic lights is needed. Based on this problem, this paper presents a pedestrian safety system at the cross roads.

Some previous researchers have researched pedestrian safety. Jia examined pedestrian identification of planar objects using imaging of light field. Recognizing fake pedestrians on planar surfaces (2-D fake pedestrians) is an important and challenging task in the field of vision of the machine because of its various applications. The 2-D pedestrian recognition method was proposed based on light field imaging and support vector machines. This method could recognize 2-D fake pedestrians with only one sensor in one exposure [1]. Wang examined detection of pedestrians through the body parts of semantic and contextual information with DNN. The Estonian Pedestrian has increased in recent years, while the handling of complex occlusion and accurate localization is still the most important problem. The section networks and contexts consisted of three branches, namely, basic branch, section branch, and the context branch. This specifically uses two branches to detect pedestrians through semantic information on body parts and contextual information, respectively. By combining output from all branches, a strong complementary pedestrian detectors with lower error rates and higher localization accuracy was developed, especially for pedestrian occlusion [2].

Xu examined signalization of multi-level pedestrians at the large four-foot roundabout. Multi-level pedestrian signalization (MPS) was developed for roundabouts to balance pedestrian accessibility and vehicle mobility. With the right application of traffic control devices and traffic detection systems, the correct road was assigned to pedestrians and vehicles in three modes that were driven. Signals at adjacent crossings could operate independently or as groups in special mode of road rights to prioritize pedestrians or vehicles [3]. Zang investigated pedestrian detection with a scale-conscious localization policy. A major obstacle to pedestrian detection lied in the sharp decline in performance in the presence of small size pedestrians relatively far from the camera. An active pedestrian detector that explicitly operates in multilayer neuronal representations of input still images was developed. More specifically, convolutional neural nets, such as ResNet and R-CNN were exploited to provide a rich and discriminatory feature hierarchy of representations, as well as early pedestrian proposals [4].

An investigation on car brakes for the safety of pedestrians was examined by Avinash. The system used a proximity sensor to detect pedestrians. The sensor was processed by a microcontroller. The data processed by the microcontroller were then released to activate the Selenoid relay moving the brake to stop the car or motorbike [5]. A pedestrian flow calculated by using image processing was examined by Madhira. The system used a camera to capture the pedestrian images which were then processed by using minicomputers. A sensor camera was installed with several tilt angle positions to detect the pedestrians [6]. A FPGA-based traffic lights controller was examined by Kishore. The system consisted of an FPGA, a seven-segment display, a traffic lights control, a red LED, and a green LED. The FPGA was used to control the traffic lights timing [7]. A low-light pedestrian detection of RGB images using multi-modal knowledge distillation was examined by Kruthiventi. The system used an RGB camera processed by using a computer. Conventional and neural network algorithms were used to process the image data [8].

An effective detecting object from traffic camera videos was examined by Shi. The system consisted of cameras installed in the traffic lights. The fast RCNN algorithm and R-FCN method were used for object detection. The cameras installed in the traffic lights were processed by using computers with both algorithms [9]. Pedestrian Re-Identification Based on Image Enhancement Strategies and Over-fitting Solutions was investigated by Ding. The camera data were inserted into the computer to be processed by using several algorithms. The LHEMR algorithm was used to process unclear image data which were processed by using Fuzzy algorithms [10]. A Test for Smart Traffic lights Control on Pedestrian Cross on the street was examined by Tian. The system consisted of a light traffic control and a context-aware and intelligent system. The system was tested in real-like conditions on the street [11]. The Method of Pedestrian Detection Based on the YOLOv3 Model and Image Enhancement by Retinex was examined by Qu. The sensor used a camera whose data were processed by using a computer. The OpenCV python algorithm was used to process image data using the YOLOv3 Model [12].

Real-time Pedestrian Traffic Light Detection was examined by Ash. A camera was used in the sensor for object detection. The camera data were processed by computer using the R-CNN algorithm, KCF Tracker, and Tiny YOLO2 [13]. The Motion Detection Sensor Application for Monitoring Traffic Direction in Smart Street Lighting Systems was investigated by Tetervenoks. The system consisted of an infrared sensor used to detect moving objects. The data from the sensor were processed with an amplifier before inserted into the microcontroller [14]. Traffic lights scheduling for pedestrians and vehicles was examined by Zhang. The system consisted of traffic lights for pedestrians and vehicles. The traffic lights scheduling was modeled with a vehicle and pedestrian flow model. The Linear integer programming algorithm was used for scheduling [15]. A classification and introduction objects from a moving laser scanning point in the cloud of the road environment was examined by Lehtomaki. The system consisted of a laser radar that functions for input sensor from the system. The method was carried out by using pre-processing and removing ground and facades. Segmentation and segmentation classification were needed to obtain location points [16].

Referring to the previous researches, a pedestrian safety system has been examined. The previous system used camera sensor and laser sensor to detect the pedestrians. Microcomputers such as Raspberry and FPGA were used to process the data from the sensors. The purpose of this paper is to present a pedestrian security system when crossing the street. The system presented in this paper is different from the previous papers. The system uses Arduino microcontroller to process sensor data and activate spray when a traffic lights violation occurs.

II. Research Method

Pedestrian crossing safety system at traffic lights intersection is divided into two, namely, system design and pedestrian crossing safety system prototype.

1) System planning: Electronic and mechanical devices used in pedestrian crossing safety system are illustrated in Fig. 1. It can be seen that the system includes microcontroller devices using Arduino Uno [17]–[20], Relay, Ultrasonic Sensor, Power Supply, and DC pump. The control system used is a programmable Arduino Uno. An ultrasonic sensor is used to detect objects using ultrasonic waves. A relay is used as a switch to turn on actuators based on the signals obtained from the sensors, while a DC pumps is the actuator for spraying water.

The design of the program decision tree algorithm [21] for pedestrian crossing safety systems is shown by the flowchart in Fig. 2 [22]–[25]. The figure describes that the power supply turns on the device to activate the traffic light system. The ultrasonic sensor will be active when the traffic light turns red and gives an input signal when there is movement of an object in front of it. The Arduino processes the input signal and sends the signal to the relay. The relay serves as an on/off switch to run the DC pump to spray water as a deterrent effect on traffic violators.

2) System prototype: The design of the prototype using Sketch-up application can be seen in Fig. 3. The figure shows that the prototype size is 80 cm long, 40 cm wide, and 10 cm high. The prototype was made as similar as possible to the condition at the traffic light crossing. The study was conducted using toy car prototypes the detection objects of the ultrasonic sensor.

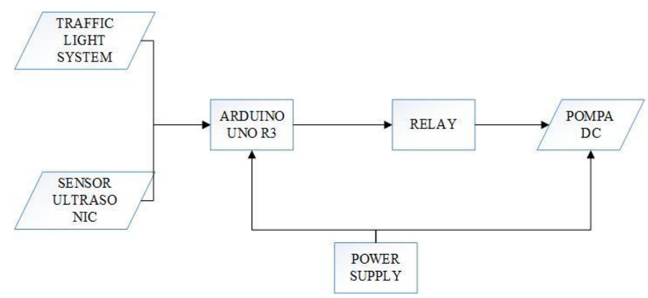

Fig. 1. Block Diagram of Pedestrian Security System.

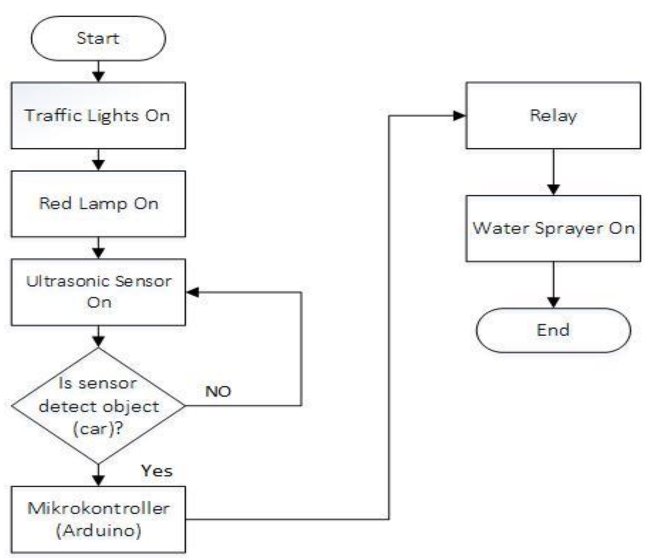

Fig. 2. The Working Principle of the Pedestrian Security.

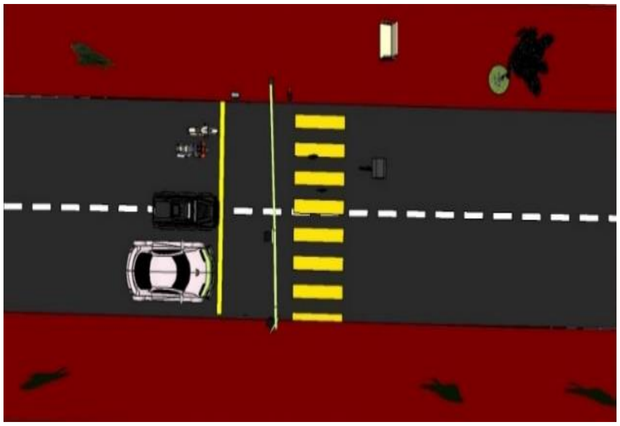

Fig. 3. Pedestrian Security System Prototype.

III. Discussion

Fig. 4 shows the test of pedestrian crossing safety system and the overall system. It can be seen that the pedestrian crossing safety system consists of three systems namely input system, control system and output system. The input system consists of a sonar sensor which is a proximity sensor. The control system is the system that processes the input, and then the microcontroller proceeds and releases it to turn on/off the relay. The output system is the system that activates the water pump to spray vehicle drivers or riders.

1) Change in sensor distance value: The test of the overall system was carried out to determine the safe distance set for the pedestrian safety system as shown in Table I. The table shows that that there are columns for the distance values set, columns for measurement values, and relay conditions. The distance values specified in this paper are 17 cm and 18 cm. The measurement test starts from the closest distance to the farthest. This paper presents the closest distance of 17 cm to the farthest distance of 22 cm. It can be seen that when the measurement distance is further than 4 cm, the system cannot detect make the relay OFF.

2) Changes in the position of the vehicle against the stop line: There were three conditions carried out in this test in which the vehicles was in position A, B, and C as shown in Fig. 5.

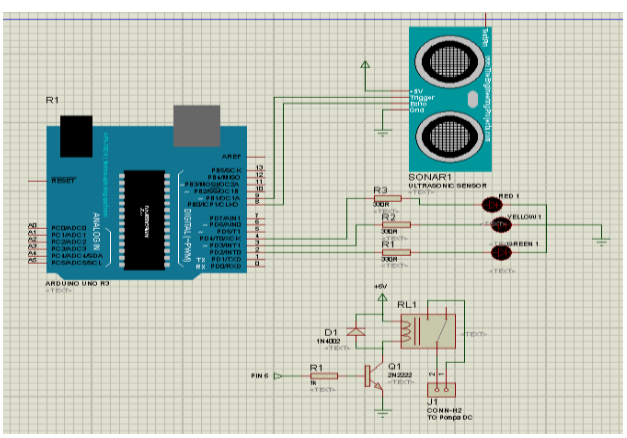

Fig. 4. Electronic Circuit of Pedestrian Crossing Safety Systems.

TABLE I. Values of Sensor Distance and Measurement Results

Data	Values set	Measurement values	Relay states
1	17 cm	17 cm	*ON*
2	17 cm	18 cm	*ON*
3	17 cm	19 cm	*ON*
4	17 cm	20 cm	*ON*
5	17 cm	21 cm	*OFF*
6	18 cm	18 cm	*ON*
7	18 cm	19 cm	*ON*
8	18 cm	20 cm	*ON*
9	18 cm	21 cm	*ON*
10	18 cm	22 cm	*OFF*

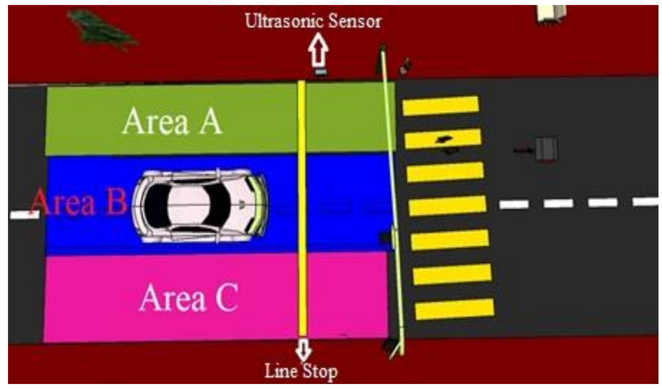

Fig. 5. Distribution of 3 Vehicle Positions (Area).

Fig. 5 shows the division of the three vehicle positions: Area A in green is closest to the sensor, Area B in blue is the middle position, and area C in pink is the farthest position to the sensor. In this experiment, the data were collected 20 times in area A, which is shown in Table II. The table is divided into columns for vehicle position, for the system and for the remark. The remark column presents TP for True Positive, TN for True Negative, and FN for False Negative, and FP for False Positive. It is seen in Table II that the negative value (-) indicates that the vehicle has not crossed yet the stop line, while the positive value (+) indicates that the vehicle has passed the stop line.

In this experiment, the data were collected 20 times in area B as shown in Table III. It can be seen that there are columns for the value of vehicle position, for the system and for the remark. The remark column shows TP for True Positive, TN for True Negative, FN for False Negative, and FP for False Positive. It can be seen in Table III that the negative value (-) indicates that the vehicle has not crossed yet the stop line, while the positive value (+) indicates the vehicle has passed the stop line. The correct value is ranging from +0.1 cm to +5 cm when the vehicle passes the stop line on which the system is ON (spraying water), and when the vehicle has not crossed the stop line or stops just on the stop line with the value less than 0 cm on which the system is OFF or water is not spraying.

In this experiment, data was collected 20 times in area B which is shown in Table IV. From the table, it can be seen that there are columns for the value of vehicle position, system column and description. In the description column, load TP which is True Positive, TN is True Negative, FN is False Negative, and FP is Positive False. In Table IV, you can see the negative value (-) in the numbers indicating that the vehicle has not crossed the stop line while the positive (+) value indicates the vehicle has passed the stop line. Correct value is when the vehicle passes the stop line which is worth +0.1 cm to +5 cm the system is ON (spraying water) and when the vehicle has not crossed the stop line or stops just above the stop line with a value less than 0 cm the system is OFF or water is not spraying. In Table IV, there are 5 errors that the system does not work correctly. This is influenced by the sensitivity of ultrasonic sensors when detecting vehicles.

TABLE II. SYSTEM STATES WHEN THE VEHICLE IS IN AREA A (NEAR THE SENSOR)

Data	Vehicle position values	System state	Remark
1	- 1 cm	*OFF*	*TP*
2	+ 1 cm	*ON*	*TP*
3	+ 2 cm	*ON*	*TP*
4	+0,4 cm	*OFF*	*FN*
5	+2,5 cm	*ON*	*TP*
6	+3 cm	*ON*	*TP*
7	+3,5 cm	*ON*	*TP*
8	+4 cm	*ON*	*TP*
9	+4,3 cm	*ON*	*TP*
10	+5 cm	*ON*	*TP*
11	+ 5,3 cm	*ON*	*FP*
12	+ 6 cm	*OFF*	*TP*
13	-1,5 cm	*OFF*	*TP*
14	-2 cm	*OFF*	*TP*
15	-2,5 cm	*OFF*	*TP*
16	+0,5 cm	*ON*	*TP*
17	-0,5 cm	*OFF*	*TP*
18	No vehicles	*OFF*	*TN*
19	+0,1 cm	*OFF*	*FN*
20	-0,1 cm	*OFF*	*TP*

TABLE III. SYSTEM STATES WHEN THE VEHICLE IS IN AREA B

Data	Vehicle position values	System state	Remark
1	- 1 cm	*OFF*	*TP*
2	+ 1 cm	*ON*	*TP*
3	+ 5 cm	*ON*	*TP*
4	-0,1 cm	*ON*	*FP*
5	+0,5 cm	*ON*	*TP*
6	+0,1 cm	*ON*	*TP*
7	+3,5 cm	*ON*	*TP*
8	+4 cm	*ON*	*TP*
9	+4,5 cm	*ON*	*TP*
10	+5 cm	*ON*	*TP*
11	+ 6 cm	*ON*	*FP*
12	+ 6,5 cm	*ON*	*FP*
13	-0,5 cm	*OFF*	*TP*
14	-2 cm	*OFF*	*TP*
15	-2,5 cm	*OFF*	*TP*
16	-0,3 cm	*ON*	*FP*
17	+3 cm	*ON*	*TP*
18	0 cm	*ON*	*FP*
19	+7 cm	*OFF*	*TP*
20	No vehicles	*OFF*	*TN*

TABLE IV. SYSTEM STATES WHEN THE VEHICLE IS IN AREA C

Data	Vehicle position values	System state	Remark
1	- 1 cm	*OFF*	*TP*
2	- 0,4 cm	*ON*	*FP*
3	+ 1 cm	*ON*	*TP*
4	0 cm	*ON*	*FP*
5	+5 cm	*ON*	*TP*
6	+3 cm	*ON*	*TP*
7	+3,5 cm	*ON*	*TP*
8	+4 cm	*ON*	*TP*
9	+4,5 cm	*ON*	*TP*
10	+5 cm	*ON*	*TP*
11	+ 6 cm	*ON*	*TP*
12	+ 6,5 cm	*ON*	*TP*
13	-1,5 cm	*OFF*	*TP*
14	-2 cm	*OFF*	*TP*
15	-2,5 cm	*OFF*	*TP*
16	+0,5 cm	*ON*	*TP*
17	No vehicles	*OFF*	*TN*
18	+7,3 cm	*ON*	*FP*
19	-0,1 cm	*ON*	*FP*
20	+0,1 cm	*ON*	*TP*

The values of precision, recall, and accuracy for each area are summarized in Table V. The table shows that area A has the highest accuracy and precision. This is because area A is the area closest to the sensor, while the lowest accuracy value is in area B due to the sensor sensitivity in detecting the presence of the vehicles.

TABLE V. VALUES OF PRECISION, RECALL AND ACCURACY OF SYSTEM

Area	Precision	Recall	Accuracy
A	94 %	*88 %*	*85 %*
B	73 %	*100 %*	*75 %*
C	75 %	*100 %*	*80 %*

IV. CONCLUSION

Based on the results of testing and discussion, it can be concluded that a pedestrian crossing safety system has been realized at the traffic lights intersection. The placement of the sensor is very influential on reading values and systems. This system is able to detect a vehicle closest to the sensor or in Area A with 85% accuracy, 88% recall and 94% precision. The system is able to detect a vehicle in area B with 75% accuracy, 100% recall and 73% precision. The system is able to detect a vehicle in area C with 80% accuracy, 100% recall and 75% precision. After the traffic violator has been detected by the system, the tool will activate the water pump. The time for water spray is ± 5 seconds.

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