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AI Based Wireless Traffic Light Detector using Image Classification in Machine Learning to Reduce Road Traffic Accidents: A Case Study of Uganda's Road Traffic

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Abstract **– Road traffic accidents in Uganda have led to many deaths. This unfortunately occurs to pedestrians, users of private and public means of transportations. Many solutions have however focused on for example: sensitization, and building wider roads. This study therefore, focused on using Artificial Intelligence in the traffic control. The results show that image classifier model can detect traffic lights with high accuracy. This implies that, the trained model can be employed in the traffic control system such that traffic control is automated so as to reduce on the driver errors that lead to road traffic accidents.**

Keywords **– Artificial Intelligence (AI), Image Classification, Traffic Lights, Radio Frequency, Robotics.**

I. Introduction

Self-Monitoring, Analysis and Reporting Technology (S.M.A.R.T.) has become an integral part of our daily lives [1], [2], [3], [4]. There have been developments in technology for the different sectors such as: industrial, medical, domestic, and transportation. Transportation is the main focus for this study. There has been a development of manual cars, followed by the automatic cars [5], [6], [7]. However, these have come with their challenges; the challenges like traffic jam, accidents [8]. The limitations that come with the automated cars require new studied solutions.

The literature review of some of the existing solutions are as follows: solutions to reduce traffic congestion [9] on roads, overriding the older system of hard coded lights which cause unwanted delays. The authors further say that reducing congestion and waiting time will lessen the number of accidents. The project can be augmented for coordination control which places traffic signals on a coordinated system so that drivers encounter long strings of green lights. This will also provide data for future road design and construction or where improvements are required and which are urgent like which junction has higher waiting times. Estimation of 25,729 crashes occurred on Ugandan roads in 2016, involving 59,077 individuals with 7,558 fatalities. This is more than twice the number of fatalities reported by the police for 2016 (3,502) but lower than the estimate from the 2018 Global Status Report (12,036) [10]. Pedestrians accounted for the greatest proportion of the fatalities. The measures devised to mitigate Road Traffic Injuries (RTI) in an emerging city like Kampala should study thoroughly the patterns of traffic and population flow to help to optimize the use of available resources for effective road safety planning, injury prevention and sustainable transport systems [11]. One of the biggest challenges facing the national dilemma of road signs illiteracy among the drivers and other road users like the pedestrians, cyclists, or motor bikes; seemed to the high rate of poor literacy among primary school children which has blamed on the poor quality of Uganda Primary Education (UPE) and general income poverty in most local communities as well as households. There is a need for a national information campaign strategy to Create or raise public awareness of the values, functions, and uses of road traffic signs (sign posts) in Uganda [12].

Problems of most of Uganda's Road Traffic Accidents (RTA) have been worsened by reckless driving on the already poor road conditions, surprising normal speed limits, poor road constructions or sub-standard work, official corruption on road projects, driving under the influence of alcohol or drug-abuse, poor driving skills, vehicles with dangerous mechanical conditions, over-loading goods or passengers [13]. The big-buses, mini-buses which are used as taxis, lorries, long-route trailers, and motor bikes (boda-boda, taxis), are some of the most affected road users in the country. The road disaster risks across the country have been attributed to reckless driving, over speeding, poor mechanical conditions of vehicles, drink-driving or alcoholism, weak bridges, bad road infrastructure, over flooding, poor training, or road rage. In most cases, over speeding, incompetent vehicles or drivers or riders or road users, have been blamed for the rising road carnage countrywide. It is imperative to involve local whistle blowers, civic education, public awareness networks, digital or ICT use, media campaigns, policy research, road policing motivations, gender equality, and international collaborations in public health research [14]. Recommendations have been suggested [15], additional measures that incorporate the role of private operators managing highway toll roads. This outcome is important as it provides policy implications that can be implemented to reduce deaths due to road traffic accidents that are currently on the rise. The fatal RTI rate in Kampala District is still almost twice as high as the global rate of 17.4 per 100,000. In addition, vulnerable road users and young adult males were the most affected category. There is thus a need to establish interventions to curb RTIs [16]. RTI prevention strategies in Kampala District should emphasize vulnerable road users (pedestrians/motorcyclists) and young adult males, who bore the highest proportional burden of RTIs. There is need to institute pedestrian safety features such as pedestrian walkways, and pedestrian crossing facilities, among others. The RTI motorcycle contribution rose steadily from 2009 to 2017 (24.5 percent to 33.9 percent). While the total number of crashes dropped from 22,461 to 13,244 between 2010 and 2017, the proportion of fatal RTIs increased from 14.7 percent to 22.2 percent [17]. Some other authors have studied wireless communication means that can be used in control systems [18], [19], [20], [21], [22], [23], [24], [25], [26].

There are so many traffic delays and traffic collisions caused by driver errors. Therefore, there is need to develop a Self-Monitoring Analysis and Reporting Technology (S.M.A.R.T.) system based on Convolutional Neural Network (CNN) [27], [28] using PictoBlox software to classify the different traffic light colours. The study concentrated on the transportation and especially the traffic control using the Artificial Intelligence (AI) [29]. AI is a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. AI is an interdisciplinary science with multiple approaches in various sectors. It is divided into different branches like: Machine Learning (ML), Deep Learning (DL), Neural Network (NN). The study concentrates on the ML extension in the PictoBlox software. PictoBlox is a graphical programming software based on the latest version of Scratch that makes coding fun and easy; it is a desktop software built to make an Arduino project simply and easily. The Convolutional Neural Network (CNN) applies the ML, DP, NN, among others, to classify images based on their features. The CNN uses colour feature to differentiate the control signals based on colour.

II. Materials and Methods

2.1. *Materials*

In this work, the following materials were used but not limited to: RF transmitter, RF receiver, PictoBlox software, robotic car, coloured Light Emitting Diodes (LEDs), breadboard, electromagnetic relay, multi-meter, batteries.

2.2. *Methods*

2.2.1. *The Design and Construction of the Transmitter and Receiver System*

The circuit designs in Fig. 1: Receiver system and Fig. 2: Transmitter system were used to construct the transmitting and receiving system.

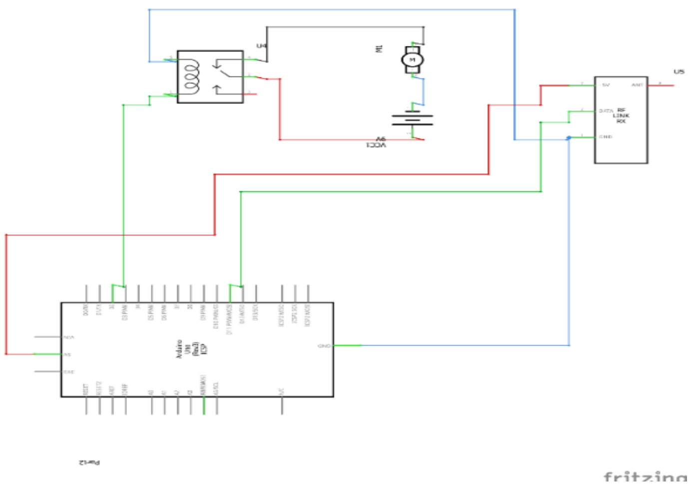

Fig. 1. Receiver system circuit design.

The micro-controller is connected to the receiver module in Fig. 1. The received signal is interpreted by the micro-controller, which then controls the electromagnetic relay. For this case, the relay either completes the circuit which turns on the motor or breaks the circuit which turns off the motor.

Fig. 2 shows a transmitter module that sends a signal to the receiver module after receiving a signal from the micro-controller. One micro-controller receives signals from the camera connected to the laptop, and the second micro-controller receives the signal from the first micro-controller which then sends an on/ off signal to the transmitter module.

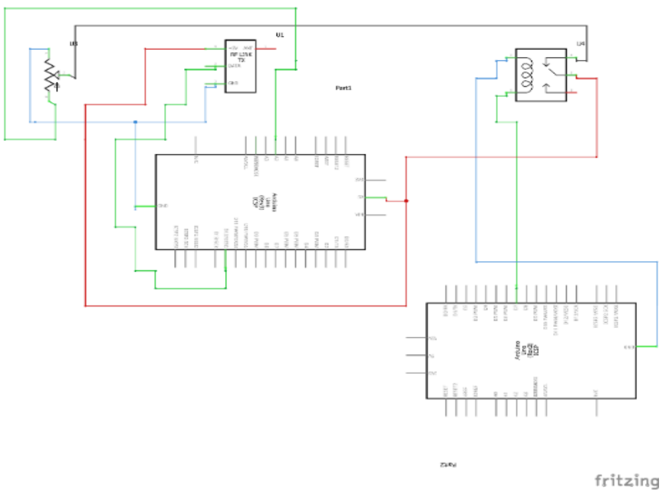

Fig. 2. Transmitter system circuit design.

2.2.2. *Building the Image Classifier Model to Detect Yellow, Green, and Red Light Emitting Diodes and Construction of the Transmitter and Receiver System*

Teachable Machine was used. It is a web-based tool that makes creating machine learning models fast, easy, and accessible to everyone.

2.2.3. *Programming of the Control System*

PictoBlox software was used to program the response code.

2.2.4. *Testing and Optimization of the SMART Traffic Light System*

The system was tested using the yellow, green, and red Light Emitting Diodes.

III. Results and Discussion

3.1. *Building the Image Classifier Model to Detect Yellow, Green, and Red Light Emitting Diodes*

Fig. 3 shows the different classes (Red, Green, and Yellow) and their respective predictions. This shows that according to the confusion matrix, red has got high prediction and zero for the other colours. This applies for green and yellow which have high predictions of their respective colours.

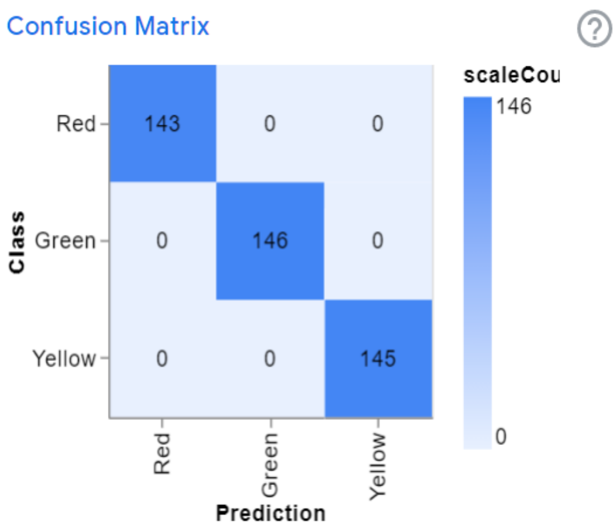

Fig. 3. Confusion matrix of the trained model in Teachable Machine.

Fig. 4 shows the accuracy with respect to the samples used. Fig. 5 shows the accuracy per epoch of the trained model. 80 epochs were used in this case. Fig. 6 shows the loss per epoch graph.

Accuracy per class

CLASS	ACCURACY	# SAMPLES
Red	1.00	143
Green	1.00	146
Yellow	1.00	145

Fig. 3. Accuracy per class of the trained model in Teachable Machine.

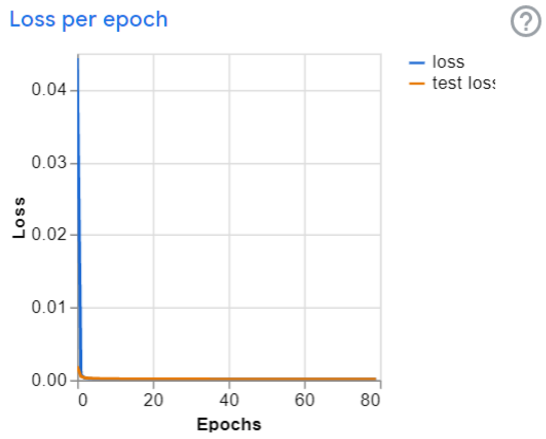

Fig. 4. Accuracy per epoch of the trained model in Teachable Machine.

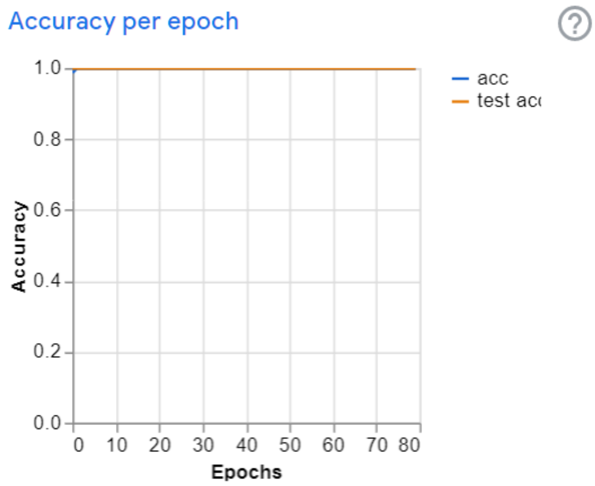

Fig. 5. Loss per epoch of the trained model in Teachable Machine.

Fig. 7 shows the testing of the trained model in Teachable Machine using the yellow LED, Fig. 8 shows the testing of the trained model in Teachable Machine using the red LED, and Fig. 9 shows the testing of the trained model in Teachable Machine using the green LED. The respective accuracy of the testing is shown below the preview window of the respective figures.

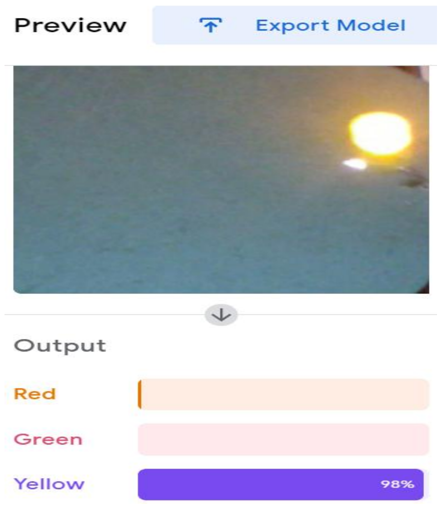

Fig. 6. Testing of the trained model using the yellow LED.

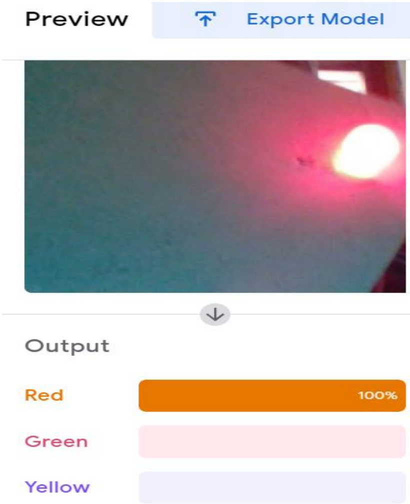

Fig. 7. Testing of the trained model using the red LED.

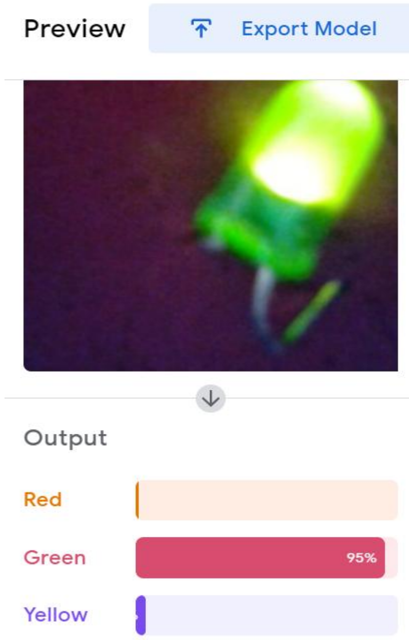

Fig. 8. Testing of the trained model using the green LED.

Fig. 10 shows the receiver system with the receiver module that reads radio frequencies and converts them to electrical signals. The micro-controller on the Arduino board reads the electronic signals and executes based on the uploaded code. The execution for this designed system is to either switch ON or OFF the electronic motor.] Receiver system: the receiver system has got the receiver module that reads radio frequencies and converts them to electrical signals. The micro-controller on the Arduino board reads the electronic signals and executes based on the uploaded code. The execution for this designed system is to either switch ON or OFF the electronic motor.

Fig. 11 shows the transmitter system with the Arduino board connected to the laptop has the PictoBlox software firmware and Machine Learning code uploaded onto the micro-controller using the PictoBlox software. The second Arduino board has the instruction code in C language uploaded onto the micro-controller. The control signal from the PictoBlox stage camera is interpreted by the micro-controller connected to the laptop.

The second micro-controller then reads the signal from the first micro-controller, which is later transmitted using he radio frequency transmitter module to the receiver module.

Fig. 12 shows the designed system connected to the robotic car.

Fig. 13 shows both the transmitter and receiver systems. The system on the left of the figure is the transmitter system and the system on the right of the figure is the receiver system that controls the robotic car motors.

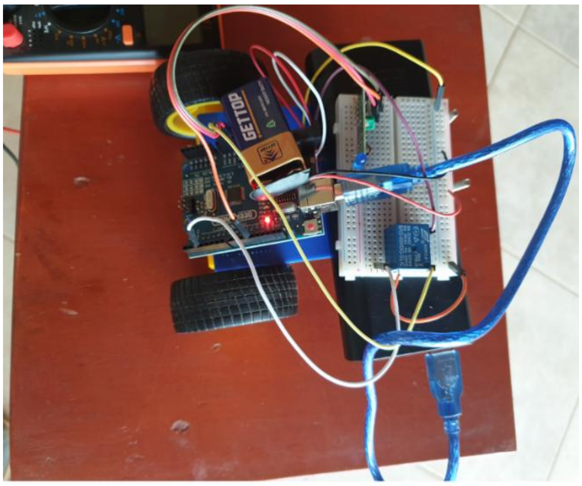

Fig. 10. Constructed receiver system.

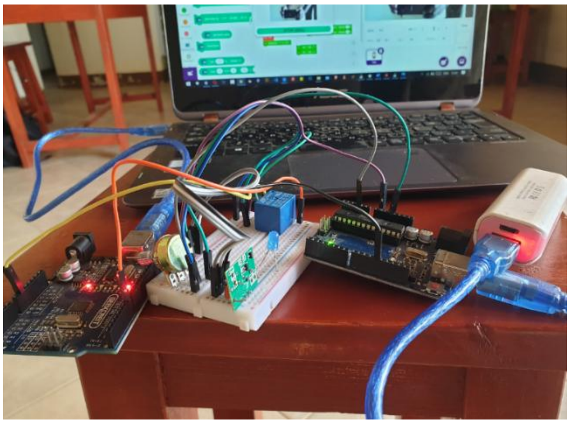

Fig. 11. Constructed transmitter system.

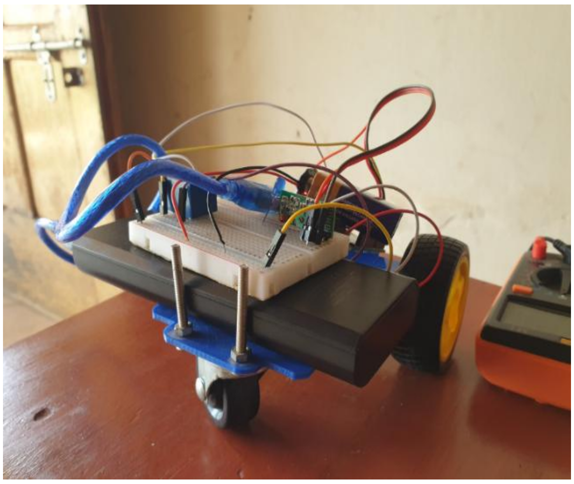

Fig. 12. Robotic car with the receiver system: the designed receiver system connected to the rover.

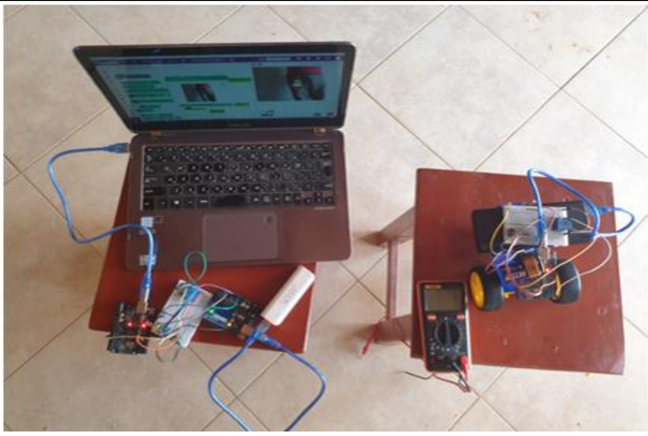

Fig. 13. Transmitter and receiver system: displays laptop's camera was used as an input to read the color signal. The designed system on the left is the transmitter system and the system on the right is the receiver system.

IV. Conclusion

Two micro-controllers were used on the side of the transmitter; one micro-controller was to accommodate the Machine Learning code through the PictoBlox software, and the second micro-controller was to accommodate the C language code through the Arduino Integrated Development Environment (IDE). Then, one micro-controller was used on the receiver system side. The trained model can detect the traffic light colours with high accuracy, and therefore this system can be employed in the traffic jam to reduce on the road traffic accidents in Uganda.

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