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Traffic Violation Detection System Using Image Processing

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ABSTRACT

Over the last three decades, the global population of human beings has increased at an exponential rate, resulting in an equal rise in the number of vehicles owned and used globally. Vehicle traffic is a major economic component in both urban and rural areas, and it requires proper management and monitoring to ensure that this mass of vehicles coexists as smoothly as possible. The amount of vehicular traffic on roads around the world, with Nigeria as a case study, results in varying degrees of traffic rule violations, especially red light jumping. To arrest offenders and resolve the weaknesses and failures of human traffic operators who cannot be everywhere at once, efficient traffic violation and number plate recognition systems are needed. There are several methods for reading characters, which can be alphabets, numbers, or alphanumeric. To minimize processing time and computational load on the machine, this research proposed k-Nearest Neighbour for plate number character recognition. The system was developed and evaluated. From the result, the localization of license plate regions within an image was 92 percent accurate, and character recognition was 73 percent accurate.

Keywords: K-Nearest Neighbour (KNN), Localization, Image Processing, Contour Mapping, Database.

1. INTRODUCTION

As the world becomes more urbanized, traffic violations are becoming more serious in many countries, and prosecuting the perpetrator by the traffic enforcement agency has become difficult due to the insurmountable traffic situation [1]. Dealing with traffic violations and accidents is a big problem in social and public management around the world [2]. The number of cars on city roads has increased significantly, causing traffic violations to become extremely severe. This results in substantial property loss as well as a rise in injuries that can threaten people's lives. [3]. Road traffic injuries and fatalities are a significant public health issue that harms economic and social growth around the world. Road injuries cause 1.35 million deaths per year, making them the world's eighth leading cause of death [4]. In 2015, 1.25 million people died in traffic crashes, according to the World Health Organization (WHO). As a consequence of drivers' reckless conduct, the high incidence of driving accidents resulting in financial damage and casualties cannot be overlooked. To discourage potentially dangerous driving action, minimize the social cost of road accidents and deaths, it is important to pay careful attention to dangerous driving habits. As a result, traffic managers around the world are continuously updating traffic laws and increasing compliance [5, 6].

The volume of vehicular traffic on roadways in Nigeria urban cities have resulted in various degrees of traffic rule violations especially jumping of red lights. An efficient traffic violation and number plate recognition systems are therefore required to apprehend culprits and overcome the limitations and errors of human traffic operators who cannot be everywhere at all times. Various approaches exist that are used in reading off characters which may be alphabets, numbers or alphanumeric. This research proposed k-Nearest Neighbour for plate number character recognition to reduce processing time and computation load on the system. The system will help in apprehending the traffic offenders thereby reducing the violators and the road crashes that are associated with it.

The remainder of the paper is structured as follows: the review of related work is presented in section 2, section 3, describes the research methodology and the flow diagram, while the result and discussion are presented in section 4. Finally, the conclusion of the research work is presented in section 5

2. REVIEW OF RELATED WORKS

The efficacy of the license plate localization technique is extremely significant in the identification and recognition of license plates. The method of deciding which part of the image, or which pixels in the image, constitutes the license plate of the vehicle captured in the image is known as license plate localization. In the field of automatic license plate recognition and detection, various studies have been performed. Many of the systems developed by various researchers in this field have been made easier to implement because of the contrast between license plate characters and the context. The same basic framework of operations used to realize image processing – effective image processing – underpins all of the methods used in these studies. Image acquisition, preprocessing of the captured image, extraction of the area of interest, and character recognition are the operations involved. Even though these operations are basic, there are various algorithms available to accomplish them. New algorithms have been developed by some researchers to increase the performance of image processing. In this section, we look at some of them.

In [7] develop an n automatic number plate recognition for the Indian vehicular traffic system. The system was developed using SURF and State Vector Machine (SVM). Using the SURF approach, the position, scale and orientation of the test image were accurately defined. Although 94% efficiency rate was achieved. The limitation of this system is that it was used only for identifying the type of vehicle, that is either Even or Odd, Commercial or Private, or Government vehicles. It was not deployed in a system to manage road traffic or help to apprehend traffic rule violators. [8] develop the vertical edge processing involves a comparison of pixels in a row-wise manner. The histogram obtained from this operation represents a sum of the difference between a pixel and its neighbours within a given row of the image. Although this system proves effective in the detection and, more importantly, localization of license plates in an image, it requires the computational power of an average personal computer to be feasible in real-time, as a result, a standalone unit may not be effective in implementing the system design. Also, [9] exploit the importance of Information and Communication Technology (ICT) and databases in real-time situations. Nine modules were used in the implementation of digital image

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processing. The limitation of this approach is the lack of widespread adoption of the proposed method so its behaviour cannot be accurately predicted.

In [10] proposed the use of Convolution Neural Networks, CNN. CNN's work by breaking down the image acquisition and processing procedures into “Plate detect” and “Char recognize” phases. The use of CNNs proffers an effective solution to vehicle identification, but the amount of data that is required to facilitate “learning” is rather large.

In [11] proposed an Artificial Neural Network (ANN) based character recognition system that can be trained to recognize and read off characters from the Nigerian license plate. The implementation of the ANN was restricted to the recognition of the charters on the candidate region that was selected as the correct one. The precision was found to be 98% and 96% for number plate extraction and recognition respectively for category 1, 95% and 91% for category 2, while category 3 has 80% in number plate extraction and 91% recognition success rate at the optimum threshold of 0.8. similarly, [12] presented the implementation of an intelligent traffic control system with real-time image processing. The method was contrasted, after implementation, with other systems that had been developed prior. This system was designed and developed to obtain various images from a given traffic intersection, send them to a server and using image processing algorithms on the server, compare the processed image to a reference image. This reference image is one obtained from the road when no vehicles were traversing it. After the comparison, the system makes a decision based on the number of vehicles detected. However, the failure of the cameras system cripples the entire traffic control system. Also, [13] in their work developed a system that depended heavily on hardware and the existence of an interconnection network linking all components of the system together. The system required that all vehicles be fitted with specially design hardware that can uniquely identify each vehicle and which can be easily read by a sensing unit placed at strategic points on the roadway. In the real sense, every vehicle traversing the road is detected and identified, however, only those vehicles that jump the red light have their information recorded and saved to a database, such that it can be easily retrieved at a later time. A timestamp is sent along with the vehicle’s particulars so that the time and date of any violation act is duly recorded.

3. RESEARCH METHODOLOGY

The system was built to capture images of vehicles that run red lights. A two-phase approach is used to accomplish this. The first is the violation identification and image capturing phase, and the second is the image processing phase, which involves license plate extraction and submitting the extracted number to a database. The model is represented in Figure 1 is a block diagram. The operations sequence of the established system is depicted in Figure 2. On the side of the lane, between the pedestrian walkway and the vehicle roadway, a motion sensor is mounted. The sensors are triggered in response to the traffic light system's red-light signal. Any vehicle that enters the intersection despite a red light is detected, a photograph of the vehicle is taken, the image is processed, and the license plate digits or characters are extracted. The extracted characters are saved in a database to be included in any future auctions.

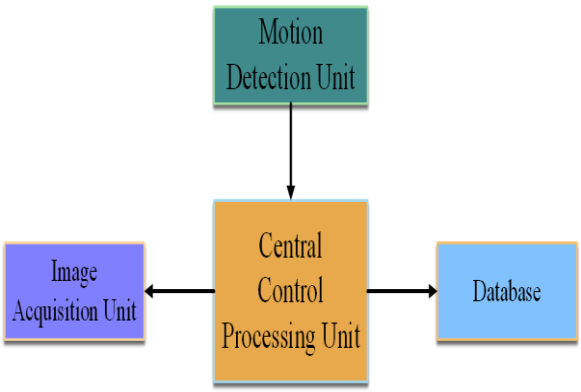

FIGURE 1. Block Diagram of the System

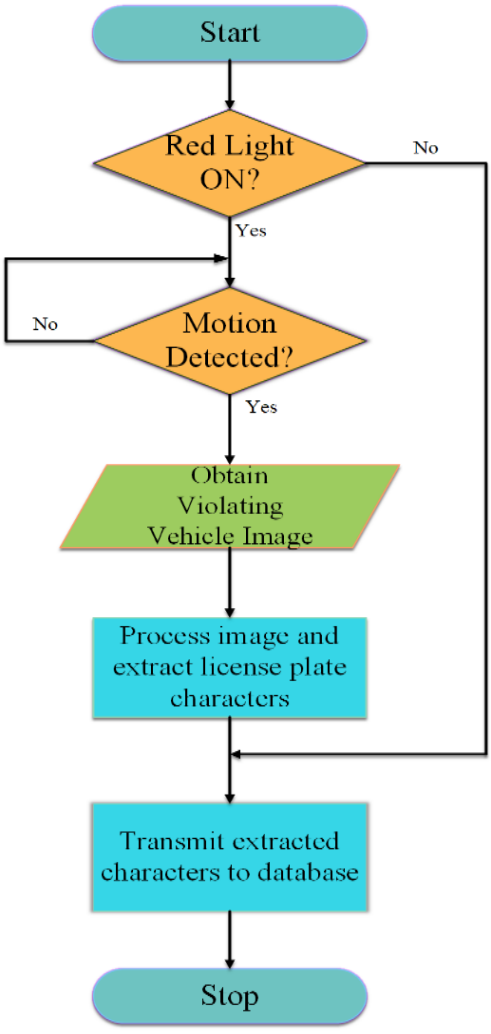

FIGURE 2. Flow Chart of the System's Operation

The developed system comprises hardware and software components that are integrated to build the real-life system. The OpenCV platform, Proteus 8 Professional, Python and support packages are the components of the software part of the entire system. The hardware component of the system comprises the camera, Raspberry Pi and PIR sensors. The implementation of this project in terms of the algorithm or approach employed is Optical Character Recognition. A dataset of license plates is used to train the system to recognize license plate and crop out such

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recognized license plates from a sample image. The characters are compared to natural numbers and alphabets to identify the subject characters by obtaining the degree of correlation between the detected plate characters and preloaded alphanumeric digits. To detect and recognize license plates from given input images, the following steps were followed in implementing the system. Violation Detection and Image Acquisition; License Plate localization; Image preprocessing; Character Segmentation; Character recognition and Character extraction and Transmission to Database.

3.1. VIOLATION DETECTION AND IMAGE ACQUISITION

At the three-way road intersection, passive infrared sensors were set up at some distance from the entrance point of each of the intersecting roadways into the intersection. These sensors will be synchronized with the red-light traffic signal, such that they are activated and deactivated at the same time for each of the roadways. During the red light, that is a "stop" period, any vehicle that crosses into the intersection – instead of stopping as it should – is detected by the infrared sensor. On detection of any violating vehicles, the camera assigned to that road section is activated and takes a picture of such a vehicle. The vehicle image obtained is transmitted to the Raspberry Pi, where an image processing algorithm is used to extract the license plate number of the said vehicle. To obtain an image of good resolution and sound image quality, the camera was elevated and placed in such a position that it can capture an image of the front of a violating vehicle. As such, the plate number will be a component of the image obtained. Figure 3 present a Three-dimensional representation of the automatic license plate detection system at the road intersection. Figure 3 is a representation of a real-world scenario that the system developed upon for the detection and record of traffic red-light violations. This diagram provides an overview of the system context of operation concerning vehicles, roadway intersection, traffic light nodes and vehicles. Cameras are oriented in a manner that enables them to obtain a full view of the roads that enter the intersection from different directions.

3.2. LICENSE PLATE LOCALIZATION AND IMAGE PREPROCESSING

License Plate Localization is a process of identifying the region of an image that contains the license plate or license plates as the case may be. In the process of Automatic License Plate Recognition, this is the most important process. A system that is to detect, recognize and read off characters from a license plate requires a sound localization operation, without which the entire process may yield inaccurate output. While image processing involves all the operations that are used to "prepare" an image to enhance the image in such a manner as to render it useful for certain operations. This research employs preprocessing as a means of enhancing license plate characters to facilitate accurate recognition and classification of these characters. The preprocessing techniques used as follows:

3.2.1. RGB (RED-GREEN-BLUE) TO GRAYSCALE CONVERSION

The original image that is obtained from the camera is a coloured image represented in the RGB format. The image is converted to an intensity image that

facilitates image processing because it uses one channel as opposed to the RGB that utilizes three channels in representing images.

$$Gray=0.2989 * R + 0.5870 * G + 0.1140 * B \quad (1)$$

3.2.2. CONVERSION OF INTENSITY IMAGE TO BINARY IMAGE

The intensity image obtained from the operation in step 1 is further converted into a binary image, that is, an image that is made up of only ones and zeros. This operation is achieved using simple thresholding such that all pixels with a value less than the threshold are assigned a value of zero (0) and those equal to or greater than the threshold are assigned a value of one (1).

3.2.3. PLOTTING CONTOUR OF INTENSITY IMAGE

A contour plot of the intensity image was obtained such that the various isolines of a matrix were given the same colour label so that related set of pixels were separated using various colours to represent each set of related pixels. This was applied to localize both the license plate regions and individual characters. Vectors of the contour regions are obtained and the region with the highest number of characters was selected as the license plate region and cropped out.

3.3. CHARACTER SEGMENTATION AND CHARACTER RECOGNITION

The enhanced image obtained from the preprocessing operations is further enhanced so that the characters on the license plate digits can be distinctly identified. The process of segmentation involves the partitioning of a digital image into segments to render it easier to read or use. In character recognition, the characters that have been segmented in the image are compared with a template of preloaded character. The degree matching is used to identify the characters, that is, the characters are recognized or identified to the preloaded templates of alphanumeric digits. The adaptive thresholding technique is used in the segmentation of the digital images obtained from the camera. After segmentation, the characters are read using the k-Nearest Neighbour (KNN) algorithm.

3.4. TRANSMISSION OF EXTRACTED NUMBER

The extracted digits of the license plate number are saved into a text (.txt) file format which is transmitted to and saved into a database. This is to ensure that the extracted license plates characters are accessible to law enforcement agents or other relevant bodies that may require such digits for surveys or other purposes. The extracted characters of the license plate are forwarded to the database using the urllib support package through the Wi-Fi connection that has been configured on the Raspberry Pi using the URL of the database.

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FIGURE 3. Three-Dimensional Representation of The Automatic License Plate Detection System

4. RESULT AND DISCUSSION

The automatic license plate detection system was designed, programmed and implemented using a Raspberry pi system. The system performance was evaluated based on the accuracy of the vehicle detection, license plate localization and character recognition. The accuracy was obtained using the relation in equation 2.

$$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+TN+FP+FN}} \times 100\ (\%) \quad (2)$$

Where TP = True positives; TN = True negatives, FN = False negatives and FP = False positives True positives are used to describe license plate regions – candidate regions – in an image that have been correctly identified by the system as license plate regions. True negatives are non-candidate regions that are handled as non-license plates. False positives are non-candidate regions that are identified as candidates. False negatives are candidate plate regions that are not identified as candidate regions. The accuracy of the system as stated above was calculated for correctly identified, localized license plate and correctly recognized characters. The Nigerian license plate consists of a scheme that utilizes the high contrast of license plate characters, and the white background that consists of the Nigerian flag in green. The localization and recognition of characters on a license plate work on the principle of the scheme. Figure 4 present the circuit diagram of the system as designed using the Proteus 8 professional integrated development environment (IDE). The road intersection under consideration is one with three roads intersecting, therefore, three cameras and PIR sensors are incorporated into the design to ensure that each of the roadways is effectively monitored. This system is a part of a larger

system that has two parts: one to control and regulate the flow of traffic and the other, which is to monitor the roadways for any red-light violation, capturing the image of the vehicle involved in the violation and subsequently, the processing of the image obtained. The system is controlled by the Raspberry Pi module that interfaces all the components – PIR motion sensors and Cameras – and performs image processing and extracted character transmission to the database. The Raspberry Pi utilizes a Wi-Fi connection to transmit the result from the image processing phase (that is the extracted license plate characters of any violating vehicle) to the online database. At the same time, the Raspberry Pi saves a copy of the alphanumeric license plate digits into its memory.

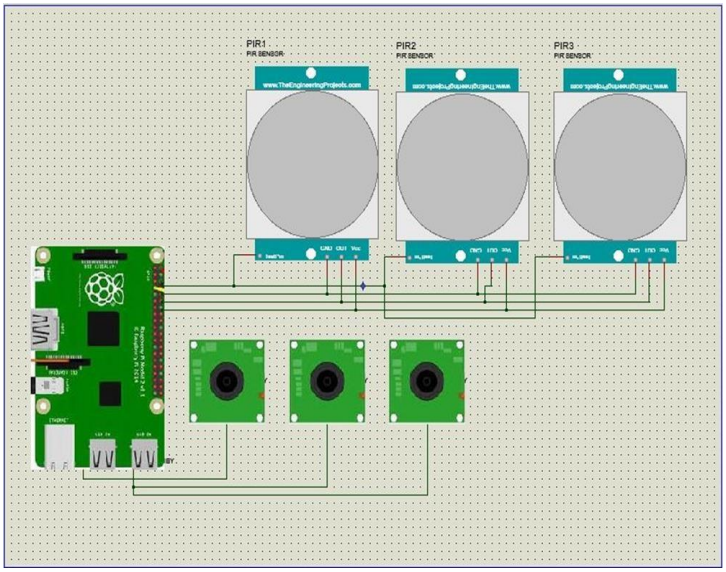

FIGURE 4. Circuit Diagram of the System

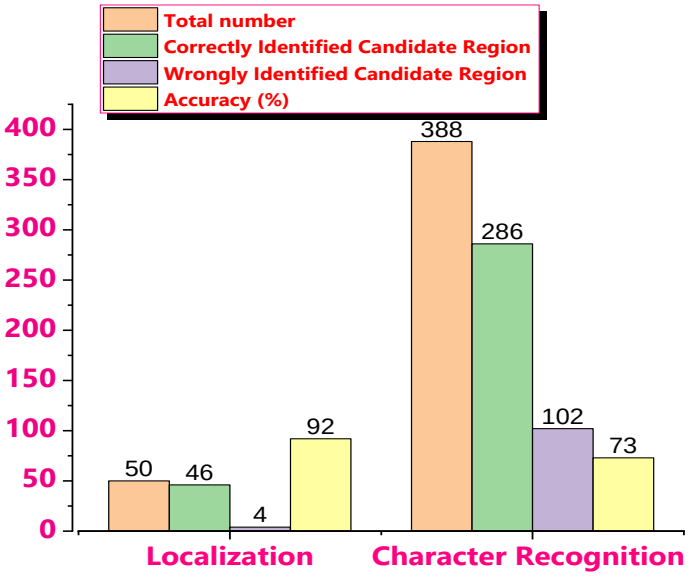

FIGURE 5. Performance Analysis of the System

The output obtained from the system developed is evaluated based on two criteria which are the degree of localization, and that of character recognition. Figure 5 present the performance evaluation using an accuracy of localization and character recognition metrics. The results as presented in figure 5, shows a high degree of

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localization of license plates. This is greatly affected by the resolution of the camera used to acquire the images and the accuracy of image cropping which is geared at zooming in on the image such that the vehicle is centred to enable the system to correctly detect the license plate and reduce the risk of error. The analysis of the system based on the degree of success in localization of license plate regions was carried out concerning the entire license plate region in the image. However, in terms of character recognition success, individual characters were considered.

Figure 6a to 6c shows the captured images from the camera, while figure 7a show the result of the conversion of the cropped license plate image from RGB representation to grayscale. RGB images are usually represented as three-dimensional arrays while Grayscale images are represented as two-dimensional arrays. Two-dimensional images facilitate image processing applications and as such the original images obtained are converted to grayscale. Figure 7b shows the output of the image segmentation using thresholding. The thresholding of the image also incorporates image binarization. Image thresholding employed for this project was adaptive such that the threshold applied to each image was dependent on the features of the image such that the threshold applied to each image varied with the image. Figure 7c presents the image from the contour mapping of the binary image of one of the license plate image analysis instances. The contour mapping involves assigning a particular colour to areas of an image that are related by common characteristics. Lastly, figure 7d presents the identification of characters and the highlighting of the identified characters using bounding boxes. The colour for the bounding boxes used in this case is green. The highlighted characters are analyzed using the k Nearest Neighbour approach. This approach recognizes characters using a similarity index to match a character with another one in a preloaded character dataset. The hardware system implementation realized using Raspberry pi and Passive Infrared sensors is presented in figure 8.

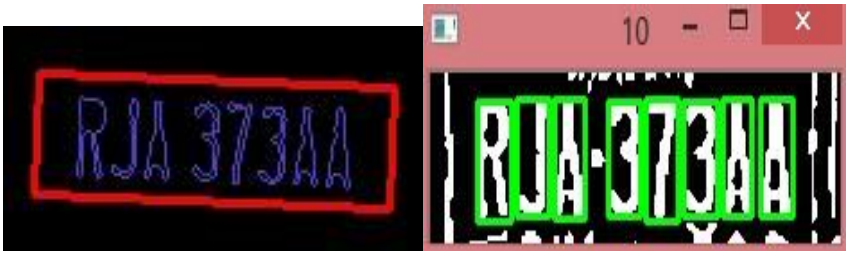
a. Accurate Output

b. Accurate Output

(c) Inaccurate Output

FIGURE 6. Output

a. Grayscale Conversion b. Threshold Image



c. Contour Mapping d. Character Recognition

FIGURE 7. Image Pra-processing

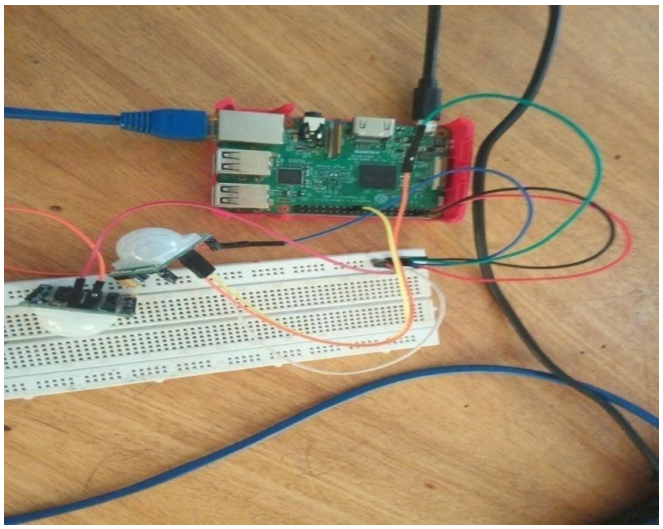


FIGURE 8. Hardware Implementation

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5. CONCLUSION AND FUTURE RESEARCH WORK

In this research, we proposed an automatic license plate number recognition system for red-light traffic violators using KNN. The system was implemented as designed. The system recognizes the right number of characters accurately. 92% accuracy for license plate number detection rate was achieved. The obtained results are encouraging and can be improved for a broader road with more lanes. The Nigerian license plate has 7 (seven) to 8 (eight) characters (alphanumeric characters). Although license plates globally have varying sizes and representation schemes, the Nigerian license plates maintain a single representation scheme with slight variations in dimension from license plate to license plate. From the result, this affects the success of the license plate detection algorithm. Future research work will be focused on a new algorithm for incorporating adaptive approaches in image processing to cater to varying dimensions of plates.

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