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A Comparative Study of Vehicle Number Plate Recognition Systems

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ABSTRACT

The traffic management based on vehicle number plate recognition in Nigeria has not recorded the much expected result because it is manually done. Having studied the existing solution, it is opined that every nation has its unique vehicle number plate, and off – the – shelf automatic number plate recognition system developed for one nation is not likely to work optimally for another nation. Despite the fact that the new Nigerian number plate system was announced in 2011, it is observed that quite a large number of vehicles on Nigerian roads still have the old number plate system. However, the system that will detect and recognize both Nigerian number plate systems has not been announced. Hence, the need to develop a system to detect and recognize both Nigerian number plate systems. Therefore, the aim of this paper is to carry out a comparative study of existing vehicle number plate recognition systems, especially for Nigerian roads and also to carry out experimental studies on Nigerian number plate recognition systems. The methodology used includes the acquisition of 934 sample images of new Nigerian number plates and 567 sample images of old Nigerian number plates. Then pre-processing of the acquired images, extraction of the identification on the number plate via character segmentation, character normalization (extracted characters reduced to 42 x 24 pixels), feature extraction and recognition of the extracted characters using template matching. From the study and analysis of the test, individual character recognition accuracy of 86% was gotten from the dataset, which shows that 791 sample images of new Nigerian number plates and 499 old Nigerian number plates were successfully recognized. Due to the errors encountered during implementation, it is recommended to create new character template with the same font as that on Nigerian number plate for accuracy.

Keywords: *Template matching, Number plate recognition system, Preprocessing, Optical Character Recognition.*

Reference Format:

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I. INTRODUCTION

The National Bureau of Statistics (NBS) in its report has disclosed that there are over 11 million vehicles in Nigeria [5]. As a result of increase in the number of vehicles in Nigeria, there is a need to develop an effective traffic monitoring system [9]. One of the ways to keep track of vehicles is by using their number plates. Each vehicle must have a license number which must be assigned to its number plate to help in traffic management and also to keep track of vehicles. It is therefore mandatory for each vehicle to have a license number which is also known as vehicle identification number ("VIN") which makes them partake in public traffic and it serves as their primary identifier after been registered. It also stands as a legal license to partake in public traffic. Registration of vehicles in Nigeria started so many years ago, but due to the fact that it is done manually, it becomes tedious to track vehicle. There is therefore an urgent need to develop an automated system that will be efficient and flexible at solving this problem. Therefore the aim of this paper is to develop a vehicle number plate recognition system for Nigerian roads. In 1976, Automatic Number Plate Recognition (ANPR) was conceived in Britain at the police scientific development branch. ANPR is known as a technology that makes use of Optical Character Recognition (OCR) on images to read the number plates of vehicles. This helps to extract the license number and recognize the alphanumeric characters on vehicle's image. ANPR is used in various ways to help support the surveillance and security of the public in conjunction with supporting efficiencies in the way we relate with transportation and vehicle - based infrastructure [22]. The introduction of vehicle number plate in Nigeria dates back to 1976 and the number plate being currently in use was announced in 1992 and was modified in 2011. The categories of vehicles in Nigeria with their attributes are shown in Table 1 [21].

Table 1 – Categories of Vehicle in Nigeria with their attributes

Year	Vehicle Type	Background Color	Foreground Color
1976 1992	Private	Black	White
	Commercial	Green	White
1992 till date	Private	White	Blue
	Commercial	White	Red
	Government	White	Green

Nigeria uses the North American standard of 14cm by 31cm for number plate as depicted in Fig. 1 [21],

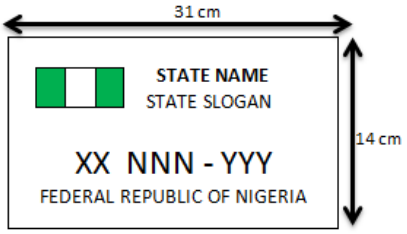

Fig. 1 – Nigerian Number Plate

Nigerian number plate consists of the flag of Nigeria, which is at the upper left hand corner of the plate. The state name and slogan are displayed at the top center of the plate and the Federal Republic of Nigeria is written at the bottom. The background has the outline of the map of Nigeria. Before the dawn of 2011, Nigeria number plate was in the format XX NNN – YYY, but it was re-arranged as YYY – NNN XX in 2011 as explained in Table 2[21]

Table 2 – Nigeria Plate Numbering System

XX	Any two alphabets (A – Z) except characters O, I, Q
NNN	Maximum of three digit numerals (0 - 9)

YYY	Three alphabets representing Local Government Area (LGA)

Plate number characters are made up of stamped alphanumeric character ridges having maximum of nine ridges. The first two ridges are the prefix alphabets followed by maximum of 3 ridges for maximum of 3 numerals, then hyphen ridge, and finally, 3 ridge character abbreviation of the Local Government Area (LGA) where the vehicle was registered. The colors used on the Nigeria number plate are shown in Table 3[21]

Table 3 – Nigerian number plate color contents

Flag	Green – White - Green	
Background	White	
Lettering	Private number plate	Blue
	Commercial number plate	Red
	Government number plate	Green
State name	Black	
State slogan	Black	
Country name	Black	

It is observed that, despite the fact that the new Nigerian number plate system was introduced in 2011, quite a large number of vehicles on Nigerian roads still make use of the old Nigerian number plate system. Hence, the need to develop a system to detect and recognize both Nigerian number plate systems. It has also come to our knowledge that a very few researchers have indeed worked on the development of ANPR system that will work optimally for Nigerian vehicles. They only worked on the old Nigerian number plate system. It is observed that the development of a number plate recognition system that will detect and recognize both the old Nigerian number plate system and the new Nigerian number plate system has not been announced. It is the aim of this research work to carry out further experimental studies and also a comparative study of existing vehicle number plate recognition system in order to address the limitation.

II. RELATED WORK

Automatic Number Plate Recognition (ANPR) has stages which are image acquisition, preprocessing of images, detection of number plate, character segmentation and character recognition [18]. ANPR was designed to adapt to various conditions such as variations in weather and lighting conditions. ANPR system has three sections as follows: plate segmentation, plate detection and plate recognition. Connected Component Analysis (CCA) technique was used for character recognition [19]. In [6], the author proposed a gate control system that uses license plate of vehicle to control the campus gate. 57 images of vehicles were tested. 95% of them were successfully recognized. In [8], ANPR system was developed for Iraqi cars. The method used includes RGB to gray conversion, image normalization and edge detection. Hough transform technique was used and a detection rate of 95% was gotten. In [7], the authors proposed Iraqi vehicle license plate recognition system. License plate detection was carried out by vertical sobel edge detection and extraction of the license plate was done via morphological operation. The system was tested with 50 images and the result gotten shows 10%

recognition rate. In [2], ANPR system with 80% accuracy was implemented. The implementation of ANPR revealed great control of traffic and helped in identification of vehicle. In [17], the author proposed ANPR framework to locate Vehicle number plates. The framework acquired images at check points. The acquired images were segmented to locate the number plate and characters were recognized via OCR. [24] developed an automatic system to detect, recognize and to count pine apple fruits in a digital still image of a farm. The method used was done by acquiring 120 images via a camera and median filter was used for noise reduction. Surf feature description and extraction were used to extract feature points. Classification was done via support vector machine. Detection and counting rates of 87.37% was gotten. In [3], Automatic vehicle license plate recognition and classification system was proposed for Nigerian vehicles. Vehicle images were acquired and water-shed morphology was used for segmentation while template matching was used for image recognition and classification. 80% accuracy was gotten during segmentation. [14] developed a Nigerian vehicle license plate detection system. The method used includes image acquisition, image conversion to gray scale, image enhancement using median filter and canny edge detector. 250 images were acquired and support vector machine was used to classify the detected regions. 98% detection rate was achieved. In [6], Automatic vehicle identification system using license plate was developed. Hidden Markov Model (HMM) was used to extract license plate features with a classification algorithm. The system was tested with 100 images. Result shows that 98% recognition rate was gotten. In [1], the authors developed a Nigerian vehicle license plate recognition system using artificial neural network. The problems encountered during the plate detection are: illumination inconsistencies, vehicle motion and complex license plate background. The system was tested with 200 images and the recognition success rate was in the range 91% to 95%.

III. METHODOLOGY

Automatic Number Plate Recognition (ANPR) system consists of the following stages namely:

3.1 DATASET ACQUISITION AND PREPROCESSING

This is the first stage to ANPR system and it tends to get the frontal image of a vehicle via a good camera. The dataset contains 1500 color images of frontal view of vehicles such as cars, jeeps, trucks, buses and tricycles. Out of which 934 sample images, are new number plate system while 567 are old Nigerian number plate. The vehicles were captured from different locations in Nigeria using Techno Camon 11 pro phone with 16 megapixels which is cost effective compared to the use of expensive digital cameras. The images were stored as color JPEG format. The preprocessing stage which helps in enhancing the image for further processing are:

(A). **RGB TO GRAY CONVERSION**

After the acquisition of the image, the next step is to convert the image (RGB format) into a gray scale image in order to reduce the quantity of data contained in the image into a manageable level without compromising its quality. The equation for converting from RGB format to gray level is shown in equation 3.1[10]

$$Y = 0.299R + 0.587G + 0.114B \quad (3.1)$$

Where R = Red color, G = Green color and B = Black

color [11]. The input image in Fig. 3.1 is a color image while the output after conversion via equation 3.1 is the gray image as shown in Fig. 3.2.

Fig. 3.1 – Input image

Fig. 3.2 – Gray scale image

(B). **GRAY TO BINARY CONVERSION**

This stage is known as Image binarization which is a process of converting gray scale image to black and white. In this method, certain thresholds are chosen to classify certain pixels as black and certain pixels as white.

The output image is shown in Fig. 3.3

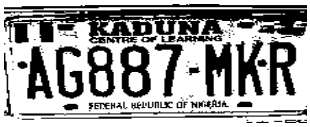

Fig. 3.3 – Gray scale to Binary Image

(C). **MEDIAN FILTERING**

Noise reduction: The noise introduced by the optical camera may cause disconnected line segments and gaps which may affect further processing. It is also known as an unwanted signal which can eradicate the quality of an image [15]. The noise is reduced via noise reduction technique called median filter. Median filter which is a non-linear filter, is used to remove impulse noise which is known as "salt and pepper noise". The following equation 3.2[20], is the median filter equation.

$$g_{new(x,y)} = \sum_{j=-1}^{1} \sum_{i=-1}^{1} * g_{old(x+i,y+j)} \qquad (3.2)$$

Where $g_{new(x,y)}$ is an intensity of light contained in the image while x *and* y are the pixels, i and j are the rows and columns in the image. The output image after median filtering is shown in Fig. 3.4

Fig. 3.4 – Median filtering on image

(D) **EDGE DETECTION**

After the conversion of gray level image into binary image, the next step is to detect the edge which is an important change of intensity in an image [16]. Sobel edge detection technique is used to locate the edges which help to locate the number plate area. Sobel operator is a two dimensional filter. The operator utilizes two 3 by 3 kernel (mask or filter) or 3 by 3 convolution matrices (G_x,G_y). The first G_x is used to detect the vertical edges while the second G_y is used to detect the horizontal edges. One estimates the gradient in x– direction while the other estimates the gradients in y – direction. In Image $G_h(x, y)$, the convolution with G_X is used to identify the horizontal edges. Where *s* and *t* are the dimensions of the image. This is clearly seen in equation 3.3[13] and equation 3.4[13].

$$G_h(x,y) = \sum_{s=-3}^{s=3} \sum_{t=-3}^{t=3} G_x(s,t) * g(x+s,y+t) \qquad (3.3)$$

The convolution with G_Y is used to identify the vertical edges $G_V(x, y)$ given by equation 3.4

$$G_v(x,y) = \sum_{s=-3}^{s=3} \sum_{t=-3}^{t=3} G_y(s,t) * g(x+s,y+t) \qquad (3.4)$$

Fig. 3.5 shows the output image after sobel edge detection.

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Fig. 3.5 - Sobel edge detection

(E) MORPHOLOGICAL OPERATIONS

This helps to connect broken strokes and decompose connected strokes via dilation and erosion. It works by combining the binary images with structuring element. A 3 by 3 matrix is used, and this processes the image, pixel by pixel according to the neighborhood pixel values. The basic morphological operations used are: (i) Dilation which is the process of improving an image by filling holes in an image, sharpen its edges, join broken strokes and lines and also increase the brightness of an image. (ii) Dilation is the operation that combines two sets. Let A and B represents subsets in 2-D space. Binary image represent 2-D space and is denoted as Z^2. Let A be the image to be processed and B the structuring element. 'a' and 'b' represent an element of image A and B respectively. c = a + b means that a = (x_1, y_1), b = (x_2, y_2), c = (x_3, y_3). That is, 'c' is the combination of both 'a' and 'b'. x and y are the pixels. It is as shown in equation 3.5[12] and equation 3.6[12]

$$A \oplus B = \{c \in Z^2 \mid c = a + b \text{ for some } a \in A, b \in B\} \quad (3.5)$$

Whereas erosion is the operation that combines two sets using subtraction of set elements and expressed in equation 3.6

$$A \ominus B = \{c \in Z^2 \mid c = a - b \text{ for some } a \in A, b \in B\} \quad (3.6)$$

The structuring element B used is of size 3 * 3. Fig. 3.6 and Fig. 3.7 show Dilated and Eroded image respectively as the output of the morphological operations.

Fig. 3.6 – Dilated image

Fig. 3.7 – Eroded image

(F). NUMBER PLATE EXTRACTION

Here, we tend to extract the candidate number plate and ignore the fake ones. This is done by using the aspect ratio of the number plate. The phases involved are:

(i) Band clipping phase: This phase is used to detect and clip the vertical area of the number plate called band by the analysis of the vertical projection of the snapshot. The horizontal projection $h_p(y)$ represent an overall magnitude of the image mapped to the y axis, this technology used assumes that the number plate is located in the horizontal band with the highest concentration of vertical edges. This is computed by the equation 3.7[13]

$$h_{p(y)} = \sum_{j=0}^{w-1} G[x, y] \quad (3.7)$$

where w is the width of the image in G, while G [x, *y*] represents the intensity of the image. *x* and *y* are the pixels contained in the image.

(ii) Plate Clipping phase: This is a horizontal selection of snapshot according to the analysis of the horizontal projection of the snap shot. Connected component labeling is used which helps to scan the image and groups it pixels into component based on pixel connectivity. This stage is concerned with exact location of the plate. The same method is used for the detection of the horizontal band which shows that the plate is the area with the height

concentration of vertical edges. To find this area in the horizontal band, the following vertical projection is used as shown in equation 3.8[13]

$$v_{p(y)} = \sum_{j=0}^{h-1} G[x, y] \qquad (3.8)$$

The vertical projection represents v_p (y) represents an overall magnitude of the image mapped to the x-axis and h represents the height of the image while x and y are the pixels

3.2 EXTRACTION OF CHARACTERS

The next is character segmentation which is isolating each character from image component. Here connected component labeling is used in such a way that each character is labeled uniquely and identifies them in the number plate. Connected components are identified as a set of series of consecutives black pixel points. Here, the character image is segmented into its subcomponents. Vertical projection is used for character segmentation. This operation works on binary images by allowing an individual values whose pixels belongs to the same connected area.

3.2.1 CHARACTER NORMALIZATION

This focuses on the removal of the variations of writings and to get standardized such as size normalization. Size normalization is used to adjust character size to a certain standard. In this step, all images are resized using bilinear interpolation algorithm.

3.3.2 FEATURE EXTRACTION

Character feature extraction is to choose a set of parameters which are the most representative of the character feature. Vertical and Horizontal projection profile techniques were used for feature extraction which tends to accumulate the black pixel along rows and columns in the image. Let S (i, j) denote the binary image in i rows and j columns for vertical and horizontal profile in the equation 3.9[13]. 'm' and 'n' denote width and height of the image respectively.

$$S(i, j) = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} S[i, j] \qquad (3.9)$$

3.3 CHARACTER RECOGNITION

The character recognition is done using Template matching or correlation. Here, characters are identified by comparing the similarities of object or character element. It checks the degree of similarities between characters and template characters. In this stage, a database that consists of 42 X 24 pixels A to Z alphabets and 0 to 9 number images are generated. The character is recognized based on the highest correlation coefficient value between the input image and the template images. The 2-dimensional cross correlation coefficient is calculated between each of the 36 templates with the characters recognized in order to identify the characters as shown in equation 3.11[10].

$$r = \frac{\sum_{i=0}^{N-1}(x_{i-}\bar{x})(y_{i-}\bar{y})}{\sqrt{\sum_{i=0}^{N-1}(x_{i-}\bar{x})^2 \sum_{i=0}^{N-1}(y_{i-}\bar{y})^2}} \qquad (3.11)$$

Where:

r – This is the 2D cross correlation coefficient.

x – Template gray level image

$\bar{x}$ - Average gray level in the template image

y – Source image

$\bar{y}$ - Average gray level in the source image

N- The number of pixels in the image

r ranges in [-1, 1]

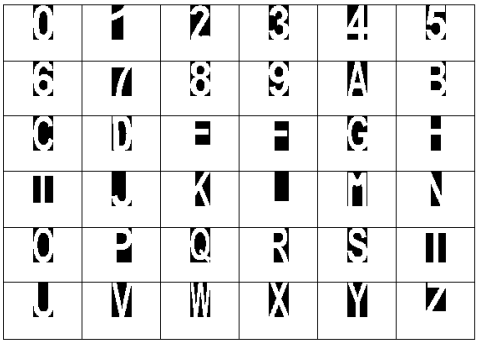
r = 1 (Template is exactly equal to image patch in the window)

r = -1 (Template is exactly equal to image patch but in opposite direction)

r = 0 (No correlation or no matches)

The template image used is depicted in Table 4

Table 4 –Template Image



The stages and the algorithmic flow afore-mentioned in the system are depicted in Fig. 3.8[4][23]

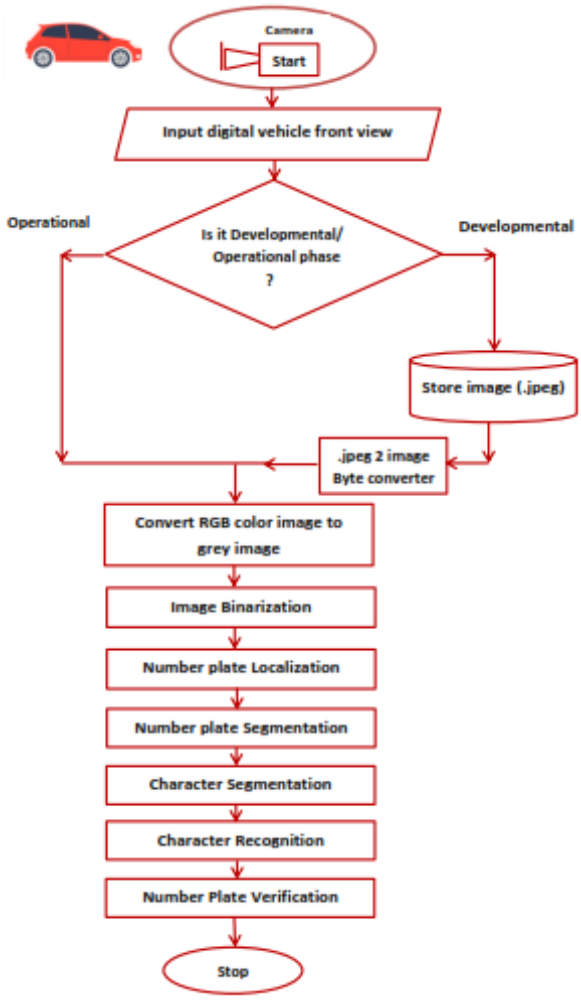


Fig. 3.8 – Block Diagram of Automatic Vehicle Number Plate Recognition System Algorithmic Flow

IV. SYSTEM IMPLEMENTATION

The sample of input data to the system contains image of Nigerian vehicles. The input data which is a 24-bit color bitmap as seen in Fig. 4.1, needs to be converted to 8-bit gray scale image using (3.1). Fig 4.2, shows the snapshot of gray scale image and was further binarized via thresholding as seen in Fig. 4.3. Fig. 4.4, shows the reduction of noise, present in the image via median filter. Edge detection via sobel operator is seen in Fig 4.5. Dilation and Erosion operations are shown in Fig. 4.6 and Fig. 4.7

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respectively. Fig. 4.8 shows number plate extraction using band clipping and plate clipping techniques. Fig. 4.9 displays the extracted alphanumeric characters.

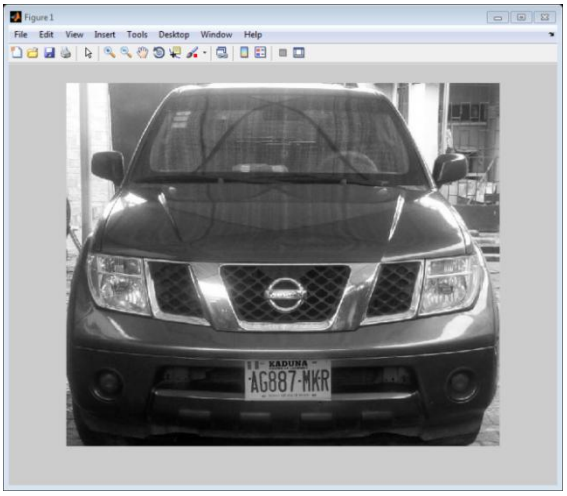

Fig. 4.1 – Snapshot of the input image

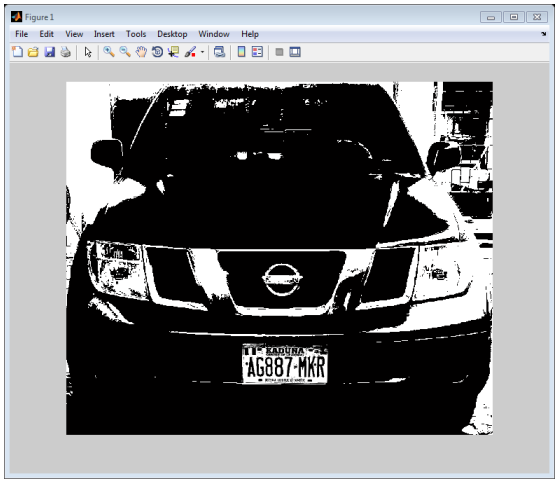

Fig. 4.2 – Snapshot of gray scale image

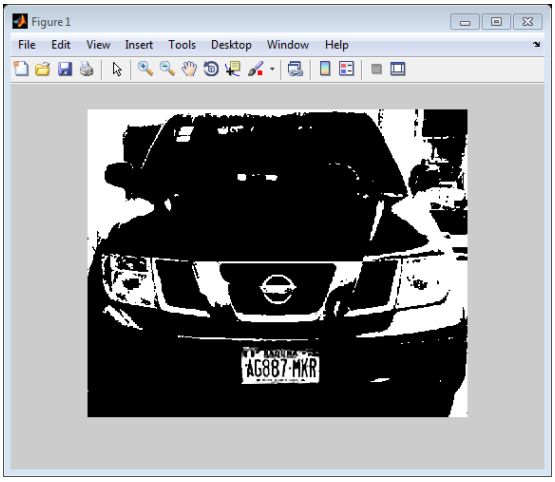

Fig. 4.3 – Snapshot of binarized image

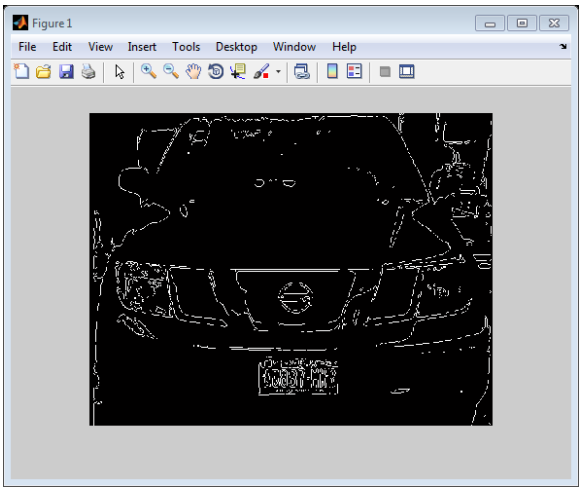

Fig. 4.4 – Snapshot of median filter on binarized image

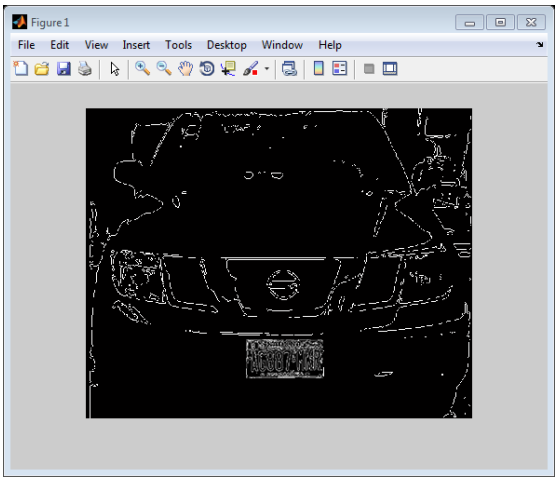

Fig. 4.5 – Snapshot of edge detection by sobel operator

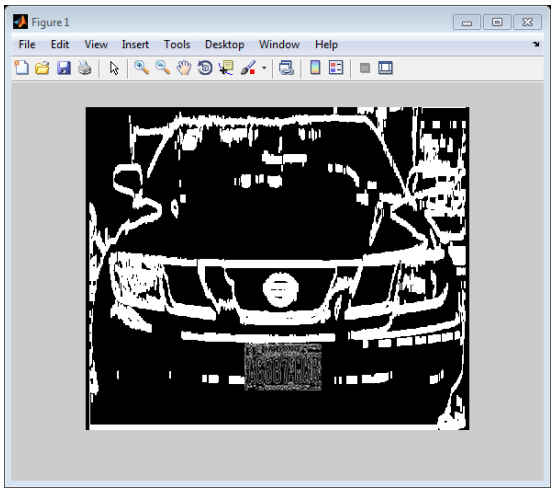

Fig. 4.6 – Snapshot of Dilated image

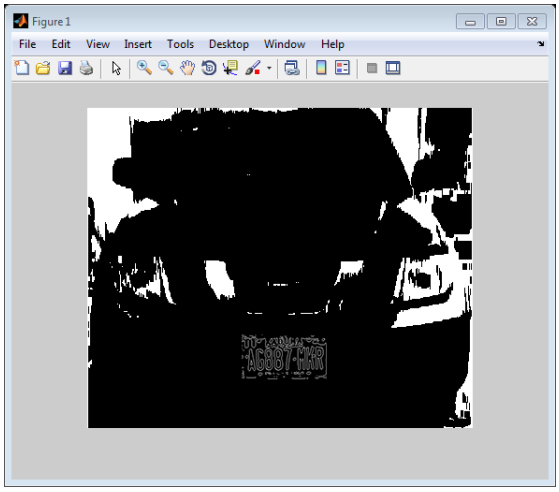

Fig. 4.7 – Snapshot of Eroded image

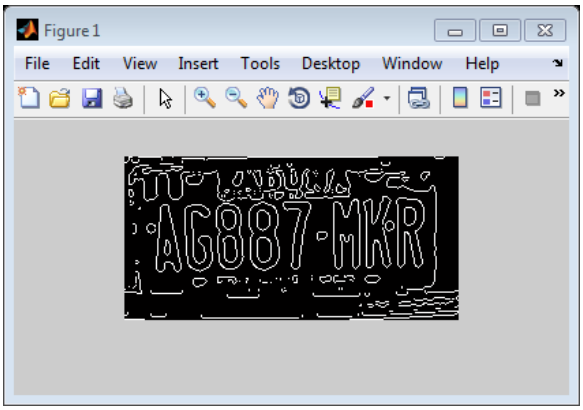

Fig. 4.8 – Snapshot of Extracted number plate via Band and Plate clipping

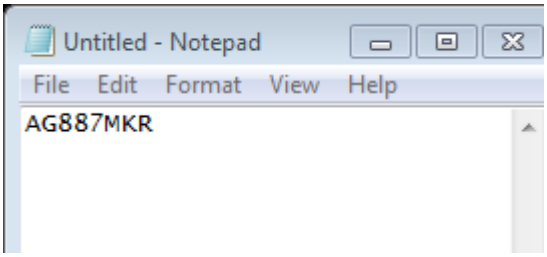

Fig. 4.9 – Snapshot of extracted alphanumeric characters

V. RESULTS

Table 5, shows the result sample and the results gotten from the system as output

Table 5 – Result Sample

SN	NUMBER PLATE	A*	B*	C*
1		KSF622AE	8	6
2		APP456CV	8	7
3		JJJ492BT	8	7
4		AG887MKR	8	8
5		AGL594EM	8	8
6		FKJ222DR	8	8
7		20A08OG	7	6

A* - Alphanumeric Characters on the number plate

B* - Number of Alphanumeric Characters on the number plate
C* - Number of Characters correctly detected

VI. DISCUSSION

The ANPR system was implemented using MATLAB 2013a. The analysis of the sample images is shown in Table 6. It was tested with 1500 sample images of Nigerian number plates, out of which 934 sample images are New Nigerian number plates while 567 sample images are old Nigerian number plates. 1290 Nigerian number plates which consist of 791 sample images of Nigerian number plates and 499 old Nigerian number plates were successfully recognized. 143 sample images of new Nigerian number plates and 67 sample images of old Nigerian number plates failed. The recognition failure was due to some constraints such as problem with template, blurred number plate, faded number plates and small sized number plates. The rate of successful recognition is 86%. The system took an average of 2.1 seconds to detect characters on number plate. The results of the test reveal the alphanumeric characters correctly detected and also those that were not correctly identified due to some afore-mentioned errors especially with the template used which allows misrepresentation of some characters such as character 'C' which was misrecognized as character 'L' and numeric character '2' which was misrepresented as character 'Z' etc.

The misrepresentation or misrecognition of the character 'C' was due to the fact that the template character 'C' in the database has a short round shape or curvature but the extracted character 'C' from the number plate has at the apices or vertices straight edge with a little round shape. The font plate type of the template used was only similar to Nigeria number plate fonts but was not the same.

Table 6 – Sample images Analysis

SN	SAMPLE IMAGES	NO OF SAMPLE IMAGES	SUCCESFULLY RECOGNIZED	FAILED
1	Old Number plate	566	499	67
2	New Number plate	934	791	143
	TOTAL	1500	1290	210

The low accuracy rate recorded in this work may be due to the fact that 1500 sample images were used instead of the 100 and 200 images in [1] and [6]. Also, in [1] and [6], it was observed that a higher recognition rates of 98% and 95% were gotten respectively compared to the 86% recognition rate gotten in this work. Also we carried out tests on both old and new Nigerian number plates unlike in [1] and [6], in which test were carried out on only old number plates.

VII. CONCLUSION AND RECOMMENDATION

Number plate recognition system via vehicle number plate is presented. Image processing technique was used to identify images of vehicle. Matlab was used to implement the system. Individual character recognition accuracy of 86% was gotten from the dataset. It is recommended that on account of the errors gotten during character recognition, there is a need for creation of new templates with the same font

as that on Nigeria number plate in order to eradicate the errors.

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