

# Nigeria Paper Currency Serial Number Pattern Recognition System for Crimes Control

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## ABSTRACT

Only secured and conducive environment void of robbery, kidnapping, fake currency and all forms of insurgencies will foster production and distribution of goods, investment and saving that enhance national economic growth and development. This is a mirage in a country generally believed and tagged the giant of African; Nigeria. Crime, in whatever name or nomenclature, has a significant negative impact on the welfare and economy prosperities of our society. The urge to get rich promotes Crime like armed robbery, kidnapping for ransom and production of counterfeit banknotes to mention but a few. Innocent people have suffered psychological distress, fear, anger, depression, physical harm, financial loss and in most cases untimely death during the operations by these hoodlums. Banks, Cash-In-Transit Vehicle, and ATM points are often robbed by gangs in search for paper currency. Kidnappers as well demand for paper currency as ransom while some other gangs are involved in the production of counterfeit banknotes so as to enrich themselves no minding the negative effect on the nation's economy. The banknotes collected during the operations by the hoodlums are taken to banks. Yet, the banks will not detect or recognize any of these notes which attest to the fact that our system lacks check and balance. The system is very porous without a recourse to this era of technology when machine is trained to do virtually everything for our convenience. Currency as an entity has a unique identification number. The identification number is an alphanumeric currency issuance of about 10 digits comprises two (2) capital letters and eight (8) numbers usually positioned at a strategic location on either front or back of the 5, 10, 20, 50, 100, 200, 500 and 1000 naira notes. It is a reliable and intelligent system developed to track banknotes unique identifiers numbers- serial numbers, in order to control financial related crimes.

**Keywords:** Nigeria Paper Currency Serial Number, Pattern Recognition

**DOI:** 10.7176/IKM/11-3-04

**Publication date:** April 30<sup>th</sup> 2021

## INTRODUCTION

Robberies, kidnapping and production of counterfeit banknotes will continue until there is a step put in place to checkmate the activities of the gangs engaged in these evils. This step is to enhance check and balance in our system in order to detect and apprehend the gangs perpetrating the evils. In this era, machine can be trained to detect the currencies carted away by robbers when cash-in –transit vehicle is intercepted, ATM or Banks are robbed, collected as ransom by kidnappers or produced as counterfeit banknotes and introduced to the economy. Armed robbers, Kidnappers and Gang producing fake currency are seizing the advantage of the Nation's lack of a system void of check and balance. If such system is implemented, the gangs should henceforth find it difficult to burgle banks, ATM points, Cash-In-Transit Van, homes and roads for cheap banknotes, for their selfish gain at the detriment of national economy and families. Indeed, very sad, many are maimed, injured or killed during their operations.

The CCTV camera installed in Banks in some cases are deactivated when the power source is switched off. This then rendered it ineffective. Banks at present have no technology or system to detect and or recognize banknotes carted from banks, collected from individual homes/roads or handled over to the kidnappers as ransom. This is ridiculous considering the advancement in the world of technology and computer age. The only device you may see available in some financial institutions and supermarkets is Ultra-Violet light used to detect counterfeit banknotes. This pre-supposes that until you get to banks you may not be sure whether some of the notes with you are fake or genuine. This singular acts had made many innocent people to suffer economic lost and embarrassment.

Leveraging on the percentage of the Citizens using Mobile Phone, a developed mobile application portable for all phones, flexible and easy to download and install to authenticate whether a banknote is genuine or counterfeit for the citizens to use will to a large extent offer on the spot verification without necessarily getting to banks before fake or genuine note is ascertained. Through the mobile app, family of the kidnapped can randomly pre-

registered some selected banknotes out of those arranged for ransom before given it out to the gangs. Once any of these banknotes is presented in the bank, the integrated cash counter serial number censor machine will flag such banknote as one of those carted away from a bank or from any of the afore-mentioned places since already marked in the internal bank's transaction log and synchronized with the national backup database at the national treasury database.

This system will indeed save the masses from economic loss and embarrassment, increase social status and improve social security. Intelligent surveillance information can be gathered through the stolen money detected at the bank leading to the arrest of the gangs involved in the act of robbery and kidnapping. This technique will enhance the anticipated check and balance that is missing in our system whereby the stolen or counterfeit banknotes are tracked and detected.

The aim of this paper is to develop a Nigerian Paper Currency Serial Number Pattern Detection and Recognition System for Crime Control. The objectives are to develop a system that will detect and recognize paper currency serial number using image processing and machine learning techniques automatically for crime control.

### REVIEW OF PAPER CURRENCY RECOGNITION SYSTEMS

Specific and related research works are reviewed in this section, with a view to identifying the motivation, objectives, methodologies, contribution of research to knowledge and limitation of the researches. Muhammad *et al* (2013) used based-edge approach to recognize and verify the Original and Counterfeit Money. The Authors were motivated to present algorithm that uses canny operator to detect the edges of paper currency. The Image used for the research was acquired from scanner. MATLAB is programmed to perform process of RGB to Gray, image binarization, noise elimination, segmentation and pattern matching. The major limitation of the research is that edge-based approach often fails to detect corners, curves where intensity level varies and complex background. But, a non-edge based technique with image filtering to remove noise will perform better. Prasanthi and Setty (2015) were motivated with the need to design a system that would be helpful in recognition of Indian paper currency notes using image processing algorithm to authenticate the currency with fast speed. Input image is acquired using digital camera with white backlighting against the paper currency so as to capture the hidden attributes. Acquired image was in RGB colour therefore converted into gray scale. Edges are detected using Sobel Operator. Image resizing is carried out as a result of the currency image that is too large to process. The Authors adopt edge based segmentation on the image. Finally, the extracted features were compared with the features of the original currency by calculating the number of black pixels of segmented image. The currency is considered to be genuine if the pixels of segmented image of the test currency are approximately equal to the pixels of segmented image. If otherwise, the currency is counterfeit. Edge-based technique used for detecting paper currency can give poor result because it is based on edge density. Hence, Sobel operators cannot detect corners. Characters that have corners can therefore be poorly detected on the paper currency. Success rate, binarization method and detailed research carried out were not reported.

Ali and Manzoor (2013) propose a recognition system of Pakistan paper currency using a KNN classifier. The motivation for the research is to present an algorithm for Parkistani paper currency that could recognize the currency accurately. The objective of the research is to develop Pakistani paper currency recognition system based on k-nearest neighbor classifier. The images used in the system were acquired from the 100, currency note set at 200 dpi through HP scanner. The colour image captured served as the input to the system and converted to the gray scale image. Wiener filter is used in order to remove noise. The image is converted to binary image so as to ease the processes of extracting features. At the completion of the preprocessing stage, extraction of the carefully selected features of the binary image is done. The features are Euler Number, Area, Height, Width, and Aspect ratio. Lastly, is the classification stage using KNN algorithm. Extracted features (train images) are stored in MAT file and matched with the test image. The research recognition ability of 100% is encouraging. Majorly, the setback in the research is the large number of extracted features that required more processing and recognition time. In addition, detailed binarization and extraction methods employed were not reported. Finally, the algorithm developed (is useful only to Pakistani paper currency notes) but lacks generality.

Various countries have different currencies both in size and colours. Therefore, most of the algorithms lack generality due to variations in size and design of the currencies across the countries of the world. It is then important to develop the algorithms that use some of the best features available in the reviewed works for Nigerian Currency Serial Number Pattern Recognition.

When this is achieved the following among others will be the benefits for the citizen; increasing confidence in the nation's currencies, improving social status, enhance monitoring and circulation of paper currency across the nation, better performance in terms of exchange of information and interactions between the national treasury database and financial institutions within the country to foster reduction of robbery and kidnapping crimes, promote a conducive commercial activities and peaceful environment.

### RESEARCH METHODOLOGY

This research work commences with the review of existing works of authorities in Paper Currency Recognition System. It is done with the intention of studying their contributions and the limitation of the existing works. Thereafter, Nigerian Currency Serial Number Pattern detection and recognition framework is presented with emphasis on addressing some of the limitations of the existing works. The proposed system uses Image Processing and Machine learning techniques to detect and recognize the paper currencies. The system is designed using Python programming language. The highlighted steps below were followed to achieve the research objectives:

The input samples used in this research were daily-used Naira Currency notes of ₦5, ₦10, ₦20, ₦50, ₦100, ₦200, ₦500 and ₦1000 (paper currencies used in the Federal Republic of Nigeria). The scanned images are in Red, Green and Blue colours. The coloured images (RGB) are resized and converted to grayscale in order to reduce the processing time using the model shown in Equation (1.1).

$$\text{Grayscale} = 0.299 * R + 0.687 * G + 0.114 * B. \quad (1.1)$$

In order to make the recognition task easier, noise is removed from the images before further processing and this is achieved with local adaptive threshold using mean filtering to smooth the images. The operation is presented in Equation (1.2).

$$C(i, j) = \sum_{k=1}^m \sum_{l=1}^n B(i+k-1, j+l-1)k(k, l) \quad (1.2)$$

$B(i, j)$  is the input of grayscale image having size  $m \times n$ ,  $m$  and  $n$  stand for the number of rows and columns respectively.  $K(k, l)$  is the filter kernel, where  $k, l \in z$  represent the dimension of the kernel and  $0 \leq i \leq m-1$ ,  $0 \leq j \leq n-1$ .

Binary images are obtained from grayscale images by thresholding. The mean  $C(i, j)$  for each window is set as the threshold  $T$  used to binarize the image as presented in Equation (1.3).

$$B(i, j) = \begin{cases} 0 & \text{if } 0 \leq C(i, j) \leq T \\ 1 & \text{otherwise} \end{cases} \quad (1.3)$$

Connected components algorithm is used to detect and group connected pixels which form objects in the binary image. The features of each object forming the binary image are examined to determine whether they form currency serial number object or not. All pixels of each connected component (object) in a binary image are assigned a unique label corresponding to the object. Objects can therefore be distinguished by their labels. For example, the area  $A$  of each object is calculated using Equation (1.4) where  $N$  and  $M$  is the dimension of the object.

$$A = \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} C(x_i, y_j) \quad (1.4)$$

$C(x, y)$  represents the object under consideration,  $x$  is the rows pixels in the object and  $y$  is the column pixels in the object. To detect the region of interest, aspect ratio of the paper currency serial number and the contiguity of the serial number characters are used. Aspect ratio is related to width and height of an image. Objects with different sizes can be identified on the basis of their aspect ratios. It usually remains the same even if the image is resized. Aspect ratio (AR) of an image is computed using Equation (1.5).

$$A.R = \text{Height of an image} / \text{Width of an image} \quad (1.5)$$

The digits of the serial numbers are segmented from the images of the banknotes using the geometric property of the region of interest. This was carried out in two stages of vertical and horizontal segmentations.

**Vertical Segmentation:** Column sum algorithm is used to detect and remove the unwanted parts of the paper currency as presented in Equation (1.6).

$$K(i) = \sum_{j=0}^{n-1} M(x_i, y_j) \quad (1.6)$$

$M(x, j)$  is the paper currency image,  $K(i)$  represents the column sums of the serial number pixels,  $i$  and  $j$  stand for the number of rows and columns in the paper currency. The average of the column sums is calculated using Equation (1.7) as presented below:

$$avg = \frac{\sum_{i=0}^{n-1} K(i)}{n} \quad (1.7)$$

$n$  represents the number of columns in the row summed image,  $K(i)$  contains the column sums,  $avg$  is the average of the column sums. The position of the column whose sum is greater than or equal to the average,  $avg$ , is set as the coordinate of the first object on the left-hand-side of the segmented paper currency and the intensity value of the pixels on this column is at 1(object area). The columns with sums less than the average,  $avg$ , are set to value 0 (non-object area).

**Horizontal Segmentation:** Column sums algorithm is used to detect and remove unwanted parts of the paper currency top and bottom parts.

**Character Segmentation:** The space between the successive characters of the paper currency serial numbers is used to detect the width of each character. Algorithm is developed to locate the space after the first character, then, it is segmented. For successive characters, the procedure is repeated until all the characters of the serial numbers on the paper currency are segmented. Extracted characters were normalized to (10 x 10) dimension showing the numbers of rows and columns in each character image.

**Character Recognition:** KNN is classified as a supervised learning algorithm in which the target is known but the pathway to the target unknown. It gives a better option to classify an unlabeled item into identified class. The value of  $k$  apparently determining the efficiency and accuracy of designed model. Gaur (2017) noted that large number for  $k$  value is advantageous in reducing the variance due to noisy data. The KNN model is popular because of its simplicity and ease of implementation to varied set of problems and effectiveness. KNN is majorly based on feature similarity. It checks for similar data point to its neighbour and thereafter classifies the data point to its most similar neighbour.

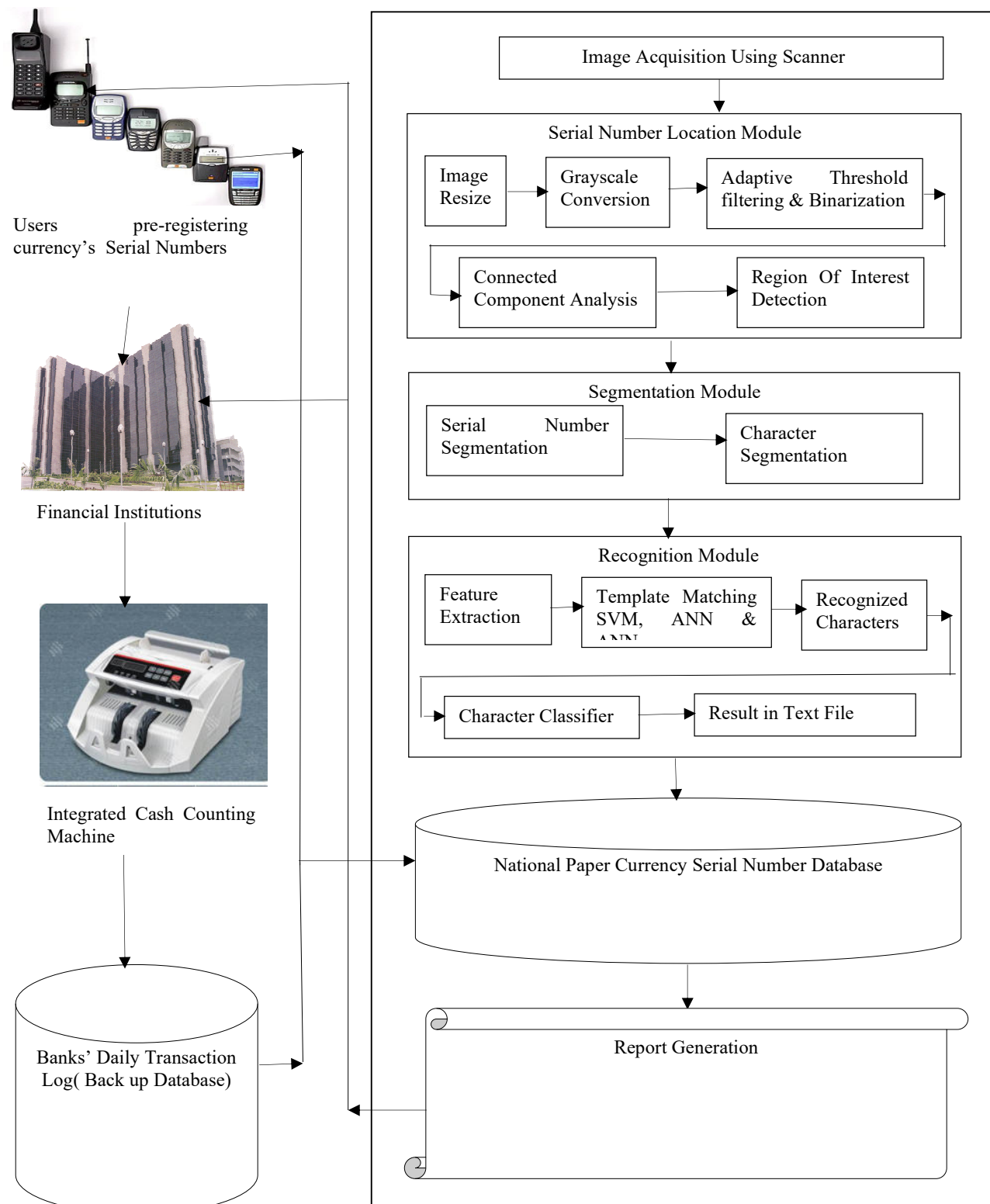
A holistic and integrated system that will fast and correctly recognized stolen or fake paper currency serial numbers making it difficult for anyone to bank and spend can be achieved by creating firstly a national database of serial numbers of all printed banknotes before distribution to the financial institutions. Secondly, every bank, daily creates a transactions log and backup database of banknotes serial numbers using integrated serial number cash counting censor machine. This machine in turns synchronizes with the national database. The technique will enable the bank to account for missing notes in case of bank/ATM robbery, give an on the spot assessment and information about the available banknotes in their custody at a particular time and day. Though currency travels very fast but the fact remains that a banknote will only reside in a particular bank or with someone at a time. Therefore, either presented at a bank or spend for a specific purpose, the action is executed by someone at a particular point. Banknotes can therefore be tracked and information gathered can be used for surveillance.

Paper Currency Serial Number Pattern Detection and Recognition System will help to manage efficiently currency circulation, detect fraudulent banknotes, improve social security, stabilize financial market, assist in surveillance information gathering and reduce financial related crimes. Overall success depends on robust performance of the hardware and software components. The hardware component recognizes the paper currency, acquires the image of the currency and transmits the captured image data. The software component processes the captured image, character extraction, segmentation and digit recognition.

## SYSTEM ARCHITECTURE

The processing of the paper currency serial number for recognition occurs in stages as stated in Qian *et al.* (2006), Prasanthi and Setty (2015), Kaur and Priyadarshi (2016) and Ghosh & Khare (2013). At each of the stages, input images are transformed from one form to the other. Image preprocessing is done to suppress undesired distortions and enhance some image features that are important for further processing or analysis like image adjusting, image smoothing as presented in Kishan *et al.* (2013); and to improve the performance of a recognition of worn, torn and noisy currency images using paper processing filter like Weiner filter as presented in Sargano *et al.* (2014) and Gaussian blurring equation to remove noise from the image as presented in Ahmed *et al.* (2013). Various algorithms have been proposed for paper currency characters' segmentation. The main challenge is to develop effective and efficient algorithm that can segment the paper currency characters regardless of the quality of the banknote and produce accurate result. Some banknotes are clean, but after some

period of circulation and usage become worn, dirty and torn. Noise is added while colour, texture and some of the security features on the banknotes are affected. In Suji *et al* (2013), it was stated that the accuracy of the segmentation algorithm determines the success or failure of the analysis procedure. Wang *et al* (2010) opine that



character segmentation will affect the degree of accuracy of character recognition and that the more precise the segmentation is, the better the recognition. Therefore, finding an appropriate segmentation algorithm is very important. The method proposed by Kaur and Priyadarshi (2016) works better when a different binarization algorithm is used. Otsu's algorithm has been an effective method but it is not compatible with serial number binarization due to the complex texture, uneven illumination and intensity variations. Otsu determines the global threshold value only for images with a bimodal distribution. It cannot be used due to the serial number that does not present a bimodal histogram pattern (Feng *et al*, 2013) but suitable for scanned documents which have constant illumination with a uniform background (Iyoti and Davinder, 2015). Digit recognition stage is the final stage of the Serial Number Pattern Recognition System (SNPR). Neural Networks technique was proposed in Pilania and Arora (2016); Sharma *et al*, (2012); and Saheed *et al*, (2013). However, the demerit of this method for real time system is that large dataset is required for much time. Sift algorithm is proposed in Akash and Tarum (2017), Hamming Distance technique is proposed in Yousry *et al*, (2018) and Hadisukmana and Yudianto (2018) proposed Template Matching. But effective noise reduction technique determines the success rate of the template matching technique.

Various recognition techniques have been used in literature. K-Nearest Neighbour (K-NN) is implemented in Kaur and Priyadarshni (2016) and reported serial number recognition rate of 83.81% while 99.50% serial number recognition rates and more than 99.60% single digit recognition rate with recognition time of 157ms in Qian *et al*, (2006). The results show that the approach is suitable for a real-time situation. Parameters required to implement it is few and no training period before prediction is made. However, appropriate tool should be used to effectively remove the noise and reduce datasets. Artificial Neural Network (ANN) approach is implemented in (Aoba *et al*, 2003; Gunaratna *et al*, 2008; Debnath *et al*, 2010; and Althafiri *et al*, 2012). Aoba *et al* (2003) report a recognition accuracy of 100%, Gunaratna *et al* (2008) also report the recognition accuracy of 100%, Debnath *et al* (2010) report the success rate of 100% while Althafiri *et al* (2012) report the success rate of 85.1%. Sheng (2013) opines that the approach has high fault tolerance, low speed recognition and therefore not ideal for a real-time situation. Also, it requires large training dataset. Template matching based approach for Serial Number Pattern Recognition was reported in Li *et al* (2010). Template matching is useful in fields such as signal processing, pattern recognition, video compression and image processing. Template matching is suitable for the situation where the background is complex and the target texture is less (Hinterstoisser *et al*, (2010). Support Vector Machines (SVM) approach for the character recognition of Serial is proposed in Li *et al* (2010). A recognition rate 98.90% using SVM was reported in Feng *et al*(2014). The merit of this approach is the ease of training the dataset. But the algorithm is complex and required huge memory. Also, choice of kernel may produce different results based on the kernel function used.

Paper currency has many features like colour, texture, size and security. Colour and texture as features on the paper currency are mostly affected by dirt and weather over a long period of use. The effect of these factors is that the banknotes may become dirty, torn, worn or fade. These visible features are therefore not reliable and dependable for paper currency detection and recognition. Serial number is one of the security features on a paper currency. Other security features on a paper currency are intaglio, security thread, and watermark among others. But in this research work serial number is used for detection and recognition of paper currency. It is chosen because it is a currency issuance number and unique identifier. No two banknotes will have similar serial number and a banknote can only reside in a particular bank at a time. To achieve a fast and correct pattern detection and recognition system for paper currency it is empirical to reduce the number of feature extracted. This is because the lower the number of extracted features the faster the processing time. The more the security features extracted from the currency notes for processing, the higher the processing time and speed. It is best to select feature(s) that would take less processing time, more discrimination power for quick and faster classification and high percentage recognition accuracy rather than processing the whole image. With appropriate recognition technique, the approach using serial number for paper currency detection and recognition is ideal for a real - time situation.

The cash counter machine is designed to detect the serial numbers on the Naira banknotes. For effectiveness and reliable system that allows for check and balance required to track criminals demanding for ransom, burgled the ATM points, producing the counterfeit notes, intercepted and robbed the cash-on-transit van, transactions log containing the banknotes serial numbers is highly indispensable. Therefore, it is a must to daily create currency transactions log. This process among other things will offer the following benefits;

- enable on the spot information about the where about of banknotes
- allows the creating of local backup database of banknotes' serial numbers in banks for proper accountability. The backup database is assessed to ascertain banknotes carted away from banks during



robbery or when the ATM point is burgled. Such detected banknotes missing can immediately marked as exhibit at the National Treasury Database. Whenever and or wherever any of the marked banknote is presented in any of the financial institution in the country, since already marked as exhibit will be flagged by counting machine. Through this, surveillance information can be gathered.

### **SECURITY FEATURES ON NAIRA NOTES**

Security features on the Naira banknotes are used for protection and easy recognition of genuine notes from counterfeits. Paper currency consists of both extrinsic and intrinsic security features. Examples of extrinsic features are size, width, colour, texture among others, when the examples of intrinsic security features are the security thread, serial numbers, and water mark among others. Among the features recognizable by touch and visibility are the raised prints, security thread and water mark. Those embossed are lettering, denominational numerals on the obverse and reverse notes. The lower denominations as shown on Figure (2.13 – 2.16) are ₦5, ₦10, ₦20, and ₦50 printed on polymer substrate, 130 X 72 mm in size, while the higher denominations as shown on Figure (2.17-2.20) are ₦100, ₦200, ₦500 and ₦1000 printed on paper substrate, 151 X 78 mm in size.

Paper currency visible features like colour, size and texture would have been the easiest and simplest method of currency recognition but could not be used because none of the visible features can stand the test of time. This is as a result of banknotes becoming worn, torn or dirty due to poor handling; holding by dirty hands, kept in a dirty environment or unnecessary exposure making the colour to fade over a period of usage. Money is an important part of human needs and very indispensable to the economic growth and commercial activities of a nation. Despite the introduction of Master Cards, the banknote is still in use by many people for their day to day economic activities and commercial transactions because of its convenience and required little education for anyone to transact business using it. All economic and commercial activities centered on money.

### **NIGERIAN PAPER CURRENCY SERIAL NUMBERS**

Customarily, every banknote has its unique serial number. Serial numbers are banknotes issuance numbers used for identification. It is for security and identification of the banknotes. The serial number on each note consists of numbers and letters differ from one country to the other. The number is printed on banknotes using special inks. The inks were magnetic and fluorescent. This is done to further enhance its security features. Magnetic inks make the banknotes to be subjected to a magnetic field during processing in sorting machines. Similarly, serial numbers printed using fluorescent ink are subjected to the ultraviolet light and if fluoresced then could be identified as genuine. These numbers are printed in different colours, font styles and sizes on some banknotes from different countries across the world.

Serial numbers are currency issuance numbers. They are used as currency identification numbers. Every banknote has its own unique serial number. The serial number on ₦5, ₦10, ₦20, ₦50, ₦100, ₦200 and ₦500 as shown on Figure (1.2 – 1.9) is made up of nine (9) alphanumeric characters or digits that differ from one another out of which two (2) characters are alphabets in capital letters while the rest characters are numbers printed on the front side of the notes. The serial number on the front side of the ₦5, ₦10, ₦20 and ₦50 is printed vertically along the left side and horizontally in the bottom right corner of the notes while on ₦100, ₦200, ₦500, it was positioned on the left lower and upper right corners of the notes horizontally but left upper, right lower sides of the ₦1000 notes as shown on Figure (1.6-1.9). However, the higher denominations ₦100, ₦200, ₦500 and ₦1000 notes are slightly bigger in size 151 x 78 mm with three distinct watermarks comprising of letter CBN, the value of the banknote and the portrait as pictured on the front of the note. The serial numbers are of the same number of digits on both the lower and higher denominations but arranged differently.



Figure 1.2: Five Naira Note (Nigerian Paper Currency)

Serial Number



Figure 1.3: Ten Naira Note (Nigerian Paper Currency)





Figure 1.4: Twenty Naira Note (Nigerian Paper Currency)



Figure 1.5: Fifty Naira Note (Nigerian Paper Currency)





Figure 1.6: Hundred Naira Note (Nigerian Paper Currency)



Figure 1.7: Two Hundred Naira Note (Nigerian Paper Currency)





Figure 1.8: Five Hundred Naira Note (Nigerian Paper Currency)



Figure 1.9: One Thousand Naira Note (Nigerian Paper Currency)

#### OVERVIEW OF CURRENCY PATTERN RECOGNITION

Pattern Recognition is a panacea to several problems of recognition or classification of objects. Mayank *et al* (2011) define pattern recognition as the science of recognizing patterns by machines, that is, the science of making machines to behave intelligently in varying environmental conditions as human in recognizing and classifying patterns into desired categories in an efficient, effective, simple and reliable manner. Gonzalez and Thomas (1978) define pattern recognition as a classification of input data through extraction important features from noisy image. It is a branch of Artificial Intelligence. Pattern recognition offers solution to the problems encountered in the classification or recognizing of objects in face, handwriting, speech, medical diagnosis, fingerprint identification, optical character, DNA sequence identification among others.

Pattern recognition enables computer to interact more effectively with humans and its environment or simply the natural world. Mayank *et al* (2011) opine that having capability of analyzing visual input data from input device like camera and having capability of making decision on input visual data gives birth to pattern recognition system on machines, which is the biggest trait of human beings. Reliable and accurate pattern recognition by machine would be of immense importance to our society.

Paper currency has for example objects like water mark, serial number, security thread and different colours among others for the sake of security. Any of the desired objects can be extracted as features and recognized by machines, most especially, serial number in case of this research work, in order to control crimes, stabilize our economy and monitor circulation of paper currency. Therefore, object detection and recognition for computer vision is one of the major factors for image understanding. Object can then be defined as a structure within a document having a specific meaning in the context of the application. Object may be character, symbol or any disconnected component. Sharma and Kaur (2013) opine that pattern recognition is a panacea to problems that fall under the category of either recognition or classification, such as speech recognition, face recognition, classification of handwritten characters, and medical diagnosis among others.

Pattern is made up of similar objects. Importantly, a pattern is an arrangement of objects in a specific order. Watanabe (1985) defines a pattern as well arranged entity; opposite of chaos. For example, the fingerprint images defined the fingerprint pattern. Therefore, pattern could be human face, speech signal, fingerprint image, web page on the internet, serial number, bar code and handwritten cursive word among others. The collection of similar objects can be grouped into a category depending on their properties. This is referred to as pattern category of class. Therefore, the pattern of objects in an image can be used to detect or recognize the image. The given objects are assigned to a prescribed category during recognition. Machine is then trained to observe the environment, distinguish patterns of interest from their background and make reasonable decisions based on the classes or category of patterns.

In a pattern recognition system, the input data is captured from the environment by using camera or scanner. Acquired data is preprocessed to remove noise or extracting pattern of interest from the background. Relevant features are extracted for recognition. Finally, the classifier based its decision on the descriptor of the extracted features. The application domain will determine the choice of sensor(s) required, preprocessing technique suitable, representation scheme appropriate, and the reliable decision making model. Also, there are different pattern recognition systems available for use in other to obtain the desired solution. In Sharma and Kaur (2013) and Mayank *et al* (2011), the methods for pattern recognition systems are:

- a) Statistical
- b) Syntactic
- c) Template Matching
- d) Neural Network.

In Statistical method, patterns are analyzed as random variables from which class densities can be deduced. Classification is done based on the statistical modeling of data. In syntactic approach, a pattern is observed as a composition of simple sub-patterns which are themselves built from yet simpler sub-patterns, the simplest being the primitives. Inter relationships between these primitive patterns are used to represent a more complex pattern. In template matching, prototype of the pattern for recognition is compared with the pattern to be recognized. The neural network approach is a self-adaptive trainable process that is able to learn to resolve complex problems based on the available knowledge. The pattern recognition algorithms among others include supervised learning and unsupervised learning.

There is need for a robust and reliable automatic banknote serial number recognition system with high processing speed and recognition accuracy. The technology of currency recognition is aimed at searching and extracting the serial numbers on paper currency for efficient classification. Pattern recognition of Naira serial number has a capability of reducing banknotes related crimes. Human effort is limited, but technology through machine learning has a super ability to deliver. Leverage on its versatility, accuracy, high speed, garbage - in garbage - out, flexibility, and 24/7 non-stop operations capabilities uniquely singled the machines out as the best offered to control crimes in Nigeria at this tech-age. Automatic recognition of Nigeria banknotes serial numbers if allowed will prevent forgery, tracked down criminals demanding for ransom, bribe and armed robbers both at homes, roads and banks. Reliable automatic banknotes serial numbers recognition system will create a positive impact on our economy and social life by reducing financial crime, improving financial market stability and social security. Businesses will thrive in a safe and secure society.



## POTENTIAL APPLICATIONS OF PATTERN RECOGNITION

The technology of pattern recognition has been applied in many fields such as artificial intelligence, computer engineering, nerve biology, medicine image analysis, archaeology, geologic reconnoitering, space navigation, armament technology and so on. It is generally used in area of science and engineering that studies the structure of observations.

With the development of modern banking services, automatic methods for paper currency recognition become very imperative in many applications such as in automated teller machines and automatic goods seller machines. The various potential applications of Pattern Recognition among others but not limited to these are explained below:

- i) Optical character recognition (OCR) is becoming an integral part of document scanners, and is also used frequently in banking and postal applications. Printed characters can now be accurately recognized, and the improving performance of automatic recognition of handwritten cursive characters has diminished significantly the need of human interaction for OCR tasks.
- ii) Automatic speech recognition is very important for user interaction with machines. Commercial systems for automatic response to flight queries, telephone directory assistance and telebanking are available. Often the systems are tuned to a specific speaker for better recognition accuracy.
- iii) Computer vision deals with the recognition of objects as well as the identification and localization of their three-dimensional environments. This capability is required, for example, by robots to operate in dynamic or unknown environments. This can be useful from applications ranging from manufacturing to household cleaning, and even for rescue missions.
- iv) Personal identification systems that use biometrics are very important for security applications in airports, ATMs, shops, hotels, and secure computer access. Recognition can be based on face, fingerprint, iris or voice, and can be combined with the automatic verification of signatures and PIN codes.
- v) Recognition of objects on earth from the sky (by satellites) or from the air (by airplanes and cruise missiles), is called remote sensing. It is important for cartography, agricultural inspection, detection of minerals and pollution, and target recognition.
- vi) Many tests for medical diagnosis utilize pattern recognition systems, from counting blood cells and recognition of cell tissues through microscopes to the detection of tumors in magnetic resonance scans and the inspection of bones and joints in X-ray images.
- vii) Many large databases are stored on the repositories accessible via Internet or otherwise in local computers. They may have a clear structure such as bank accounts, a weak structure such as consumer behavior, or no obvious structure such as a collection of images. Procedures for finding desired items (database retrieval) as well as to learn or discover structures in databases (data mining) are becoming more and more important. Web search engines and recommender systems are two example applications.
- viii) Banking Applications: Detection of counterfeit notes and many other automatic banking operations like bank cheque processing, Automated Teller Machine (ATM),
- ix) Automatic Selling of Goods: Automatic machines capable of recognizing banknotes are used in automatic dispensers of different products like cigarettes, bus tickets, vending machines,
- x) Vehicle License Plate Recognition,
- xi) Assisting visually impaired people.

## CONCLUSION

The proposed system uses the serial numbers for the paper currency detection and recognition. The extracted feature allows for a fast and correct pattern detection and recognition system for paper currency. This is because the lower the number of extracted features the faster the processing time. The more the security features extracted from the currency notes for processing, the higher the processing time and speed. It is best to select feature(s) that would take less processing time, more discrimination power for quick and faster classification and high percentage recognition accuracy rather than processing the whole image. With appropriate recognition technique, the approach using serial number for paper currency detection and recognition is ideal for a real - time situation.

## References

Allah Bux Sargano, Muhammad Sarfraz, Nuhman Haq (2013): Robust features and paper currency recognition system. ICIT 2013, The 6<sup>th</sup> International Conference on Information Technology, May 2013.

Allah Bux Sargano, Muhammad Sarfraz, Nuhman Haq (2014): An intelligent system for paper

- currency recognition with robust features by Allah Bux Sargano, Muhammad Sarfaz, and NuhmanUI Hag, 1064-1246/14/ & 27.50, 2014 – 10s press. Available at [researchgate.net /.../ 264533153\\_An\\_Intelligent\\_system\\_for\\_paper\\_currency\\_recognition\\_with\\_robust\\_on](http://researchgate.net/publication/264533153_An_Intelligent_system_for_paper_currency_recognition_with_robust_on) 22/2/19.
- A Gonzalez, L.M. Bergasa, J.J. Yebes, and S. Bronte (2012): A character Recognition Method in Natural Scene Images. In proceeding 21<sup>st</sup> International Conference on Pattern Recognition. PP.621-624, Tsukuba, 2012.
- Ahmad Saheed Mohammad, Ahmed Khalaf Hamoudi, Yasmin Abdul Ghani AbdulKareem(2013): Handwriting Numbers detection using Artificial Neural. Available at [researchgate.net /publication/313360710\\_Hand\\_Writing\\_Numbers\\_detection\\_using\\_Artificial\\_Neural](http://researchgate.net/publication/313360710_Hand_Writing_Numbers_detection_using_Artificial_Neural). Downloaded on 14/2/2019.
- Ahmed Yousry, Mohammed Taha, Mazen M.Selim.(2018): Currency Recognition System for Blind people using ORB Algorithm. International Arab Journal of Information Technology 5(1): 3440. January 2018. Available at [researchgate.net /.../329487411\\_Currency\\_Recognition\\_System\\_for\\_Blind\\_people\\_using\\_ORB\\_Algorithm](http://researchgate.net/publication/329487411_Currency_Recognition_System_for_Blind_people_using_ORB_Algorithm). Downloaded on 2/12/19.
- Ajay Kumar Boyat and Brijendra Kum Joshi (2015): A Review Paper: Noise Models in Digital Image Processing Signal & Image Processing. An International Journal, Vol. 6, No 2, April 2015.
- Akash Gupta, Tarun Sharma (2017): The propose currency detection technique based on sift algorithm and Bayesian classifier: A Review. IJSTE –International journal of science technology and engineering. Vol. 4, Issue 2, August 2017. ISSN (online): 2349 – 784x. Available at [www.ijste.org](http://www.ijste.org).
- A. Rehman, D. Mohammad, and G. Sulong (2009): Implicit Vs Explicit based script segmentation and recognition: A performance comparison on benchmark database. International Journal Open problems Compt. Math; Vol. 2, PP.352-364,2009.
- Ali and Manzoor (2013):
- Alka Pandey, K.K. Singh (2015): Analysis of Noise Models in Digital Image Processing: International Journal of Science, Technology and Management, Vol. 4, Issue 01. ISSN (Online): 2394-1537. [www.ijstm.com](http://www.ijstm.com)
- Amol A.Shiosath, S.D Bharkadei (2013): Survey of Currency recognition system using image processing International Journal of Computational Engineering Research, Vol. 3, Issued 7,36-40.
- Andrey Krenker, Janez Bester and Andrejkos (2019): Introduction to the Artificial Neural Networks. Available at [cdn.intechweb.org/pdfs/14881.pdf](http://cdn.intechweb.org/pdfs/14881.pdf). Downloaded on December 8<sup>th</sup> 2019.
- Angell, I., Kietzmann, J. (2006): "RFID and the end of cash?" (PDF). *Communications of the ACM*. **49** (12): 90–96. doi:10.1145/1183236.1183237. Archived from the original (PDF) on 2014-02-24. Retrieved 9 November 2018.
- Anazodo, R. O., Okoye, J. C. & Chukwuemeka, E. O. (2012): Civil service reforms in Nigeria: The journey so far in service delivery. *America Journal of Social and Management Sciences*. Retrieve From:<http://www.scihub.org/ajsms/pdf/2012/1/ajsms-3-1-17-29.pdf>.
- Anita Yadav, Anil Khatak (2018): Survey on Image Restoration Techniques. International Journal for Technological Research in Engineering, Vol. 5, Issue 4, December 2017. ISSN (Online): 2347-4718.
- Asano, A. (2004): Pattern Information Processing: Pattern Recognition, Support Vector Machine

- and Kernel Method. Retrieved 10 January, 2020 from <http://svms.org/tutorials/Asano2004.pdf>
- Anas M., Ali Fattouh (2015): A Non-Parametric approach for paper currency recognition. International journal of computer science and software engineering, vol. 4, issue 5, May 2015. ISSN (Online):2409-4285. [www.IJCSSE.org](http://www.IJCSSE.org).
- Automatic Identification and Data Collection (AIDC) Archived May 5, 2016, at the Way back Machine.
- Bhawani Sharma, Amandeep Kaur, Vipran Vipran(2012): Recognition of Indian paper currency based on LBP. International journal of computer applications 59(1). December 2012.
- Bouman C.A. (2020): Digital Image Processing, January 7, 2020. Available @ [engineering.purdue.edu/bouman/ece637/notes/pdf/Tristimulus.pdf](http://engineering.purdue.edu/bouman/ece637/notes/pdf/Tristimulus.pdf)
- B. Sai Prasanthi, D. Rajesh Setty (2015): Indian paper currency authentication system using image processing. International journal of scientific research engineering and technology, Vol. 4, ISSN 2278-0882, September 2015. Available at [www.ijret.org](http://www.ijret.org)
- B. Yernanarayan (2005): Artificial Neural Networks. New Delhi 10001, Prentice, Hall of India, 2005.
- BO-Yuan Feng, Mingwu Ren, Xu-Yao Zhang and Ching Y. Suen (2014): Automatic recognition of serial numbers in bank notes, pattern recognition (2014), <http://dx.doi.org/10.1016/j.patcog.2014.02.011>
- BO-Yuan Feng, Mingwu Ren, Xu-Yao Zhang and Ching Y. Suen (2013): Extraction of serial numbers on banknotes. 2013 12<sup>th</sup> International conference on document analysis and recognition. 1520-5363/13 @ 2013 IEEE DOI:10.1109/ICDAR.2013.143.
- BO-Yuan Feng, Mingwu Ren, Xu-Yao Zhang and Ching Y. Suen (2014): Part-Based High Accuracy Recognition of serial numbers in Bank Notes.
- Carpenter, G and Grossberg, S. 1990: ART3: Hierarchical search using chemical transmitters in self-organizing pattern recognition architectures. Neural Networks 3,129-152.
- Cole N. L, (2017): What is a Norm? Why does it Matter? ThoughtCo. Available at: <https://www.thoughtco.com/why-a-norm-matter-3026644>.
- Danti,A. and Nayak, K. (2014): Grid Based feature extraction for the recognition of Indian currency notes. International Journal of latest trends in Engineering and Technology, Vol. 4, Issue 1.
- D.A.K.S. Gunaratna, N.D.Kodikara, H.L. Premaratne(2008): ANN based currency recognition system using compressed gray scale and application for Sri Lankan Currency notes. SLCRec, World Academy of Science, Engineering and Technology 21 2008, 235-240.
- Diyva Gilly, Kumudha Raimond (2013): License plate recognition – A template matching method. Diyva Gilly, Kumudha Raimond / International journal of engineering research and applications, ISSN: 2248-9622, [www.ijera.com](http://www.ijera.com). Vol. 3, Issue 2, March-April 2013.
- Debnath K.K., Ahmed S.U., Shahjahan MD., Md., Murase K., (2010): A paper currency recognition system using negatively correlated neural network ensemble. Journal of multimedia. Vol. 5, Issue 6, 560-567.
- ECB, (2001): Euro banknotes embedded with RFID chips, available at <https://www.fleur-de-coin.com/images/eurocoins/eurobanknotes.jpg>. Downloaded on 11/01/2019

- Egbefo D.O., (2014): Internal Security Crisis in Nigeria: Causes, Types, Effects and Solutions; Vol3(4), S/NO 12, September, 2014: 176-195. ISSN: 2225-8590 (Print) ISSN 2227-5452 (Online). DOI: <http://dx.doi.org/10.4314/ijah.v3i4.13>. Available at :Adapted from <https://www.xenonstack.com/blog/artificial-neural-network-applications/>
- Er. Ravi Garg and Er. Abhijeet Kumar (2012): Comparison of Various Noise Removals Using Bayesian Framework. International Journal of Modern Engineering Research, Jan. – Feb., 2012, Vol. 2, Issue 1, 265-270.
- Ebtesam Althafiri, Muhammad Sarfraz, Muhannad Alfarras (2012): Bahraini paper currency recognition. Journal of advanced computer science and technology research, June 2012, vol. 2, no 2.
- Eshita Pilania, Bhavika Arora (2016): Recognition of fake currency based on security thread feature of currency. International journal of Engineering and Computer Science. ISSN: 2319-7242, Vol 5, Issues 7, July 2016, Page no:17136-17140.
- Gavrila D.M. and Philomin V.(1999): Real-time object detection for “smart” vehicle. In: proceedings of the seventh IEEE international conference on computer vision. IEEE; 1999, VOL. 1. DOI:10.1109/ICCV.1999.791202.
- Gonzalez R.C, Thomas M.G (1978): Syntactic Pattern Recognition: An Introduction, Addison Wesley, Reading, MA, 1978.
- Govindaraj V., Sengottaiyan G. (2013): Survey of Image Denoising using Different Filters. International Journal of Science, Engineering and Technology Research, February 2013, Vol. 2, Issue – 2.
- Gursharan Kaur, Rakesh Kumar, Kanaljeet Kainth (2016): A review Paper on Different Noise Types and Digital Image Processing . International Journal of Advanced Research in Computer Science and Software Engineering. Available online at: [www.ijarcsse.com](http://www.ijarcsse.com), Vol. 6, Issue 6, June 2016.
- Hadsiski, Filev, P.Chan, J. Sahiner, B.Helvie, M.A Roubidovx, (2008): Computerized Detection and Classification of Malignant and Benign Micro-calcifications on Full Field Digital Mammograms. Springer INDIA, Vol, 5116, 2008.
- Hanish Aggarwal, Padam Kumar, (2012): Indian Currency note denomination recognition in colour images, international Journal on Advanced Computer Engineering and Communication Technology (2012): Vol-I, Issue:1, ISSN:2278– 5140, 12–18.
- Himani Bhavsar, Mahesh H. Panchal (2012): A review or support vector machine for Data Classification. International Journal of advanced research in Computer Engineering & Technology, Vol. 1, Issue 10, December 2012.
- Hassanpour H., Yaseri A., Ardeshiri G. (2007): Feature extraction for paper currency recognition. International symposium on signal processing and its application (ISSPA), Sharjah, UAE.
- Hinterstoisser Stefan, Lepetit Vincent, Hie S. P. Fua, N. Navab, (2010): Dominant orientation templates for real-time detection of textureless objects. IEEE Computer vision and pattern recognition, San Francisco, CA, 2010, dot: 10.1109/CVPR. 2010.5539908 downloaded on 19/9/19.
- Huiyi Zhou, Jiahua Wu and Jianguo Zhang (2010): Digital Image Processing – Part 1 @ 2010 Huiyi Zhou, Jiahua Wu and Jianguo Zhang & Ventus Publishing APS ISBN 978-87-



- 7681-541-7. Available at [books.google.com.ng/books?id.](https://books.google.com.ng/books?id.) Downloaded on 25/8/19.
- Ingulkar Ashwini Suresh, Prof. P.P. Narwade (2016): Indian Currency Recognition and Verification Using Image processing. International Research Journal of Engineering and Technology (IRJET). T-ISSN: 2395-0056, P-ISSN:2395-0072.
- Itay Bay-Yosef, Isaac Beckman, Klara Kedem, Itshak Dinstein, (2007): Binarization, Character extraction and writer identification of  
///historical Hebrew calligraphy documents, International Journal of Document Analysis and Recognition, Vol. 9, issues 2-4, April 2007.
- Iyoti Rani, Davinder Parkash (2015): Degraded Document Image Binarization Techniques. International journal of current engineering and technology, E-ISSN 2277 – 4106, P-ISSN 2347 – 5161,available at <http://inpressco.com/category/ijcet>.
- Jagadish H. Pujar, Kiran S. Kumar (2010): A Novel Approach for Image Restoration via Nearest Neighbour Method. Journal of Theoretical and applied Information Technology. [www.jatit.org](http://www.jatit.org)
- Jaya Tripathi, Neha Dixit, Akanksha Pandey and Pankaj Kumar: Automatic detection of fake paper currency using MATLAB. Available @ [https://www.academia.edu/33610034/Automatic\\_detection\\_of\\_fake\\_paper\\_currency\\_using\\_MATLAB](https://www.academia.edu/33610034/Automatic_detection_of_fake_paper_currency_using_MATLAB). Downloaded on January 12th 2019.
- Jency Titus, Sebastian Geroge (2013): A comparison study on different interpolation methods based on satellite images. International journal of engineering research and technology (IJERT), ISSN:2278-0181, Vol.2, Issue 6, June 2013.Avaliable @ <https://ijert.org/research/a-comparison-study-on-different-interpolation-methods-based-on-satellite-images-IJERTV2IS60011.pdf>. Downloaded on 17/01/2020.
- Ji Qian, Dongping Qian, Mengjie Zhang (2006): A digit recognition system for paper currency identification based on virtual machines. Technical report CS-TR-06/11. Available at [researchgate.net/.../4255913\\_A\\_Digit\\_Recognition\\_System\\_for\\_Paper\\_Currency\\_identification\\_Based...](https://researchgate.net/publication/4255913_A_Digit_Recognition_System_for_Paper_Currency_identification_Based...)
- Kalpana and Harjinder Singh (2015): Review Paper to Study the Image De-noising Techniques. Vol. 2, pp.127-129, Nov. 2015
- Kanchan B. Zende, Varsharani Kokare, Sunetra Pise and P.S.Togrikar (2017): Fake note detection system. International journal of innovative research in technology, IJIRT 144578 @ June 2017, vol. 4, Issue 1, ISSN: 2349-6002.
- Kavallieratou, E: (2005): A Binarization Algorithm specialized o Document Images and photos. In 8<sup>th</sup> Int. Conference on Document Analysis and Recognition, pp.463-467 (2005).
- Kedar Sawant, Chaitali More (2016): Currency Recognition Using Image Processing and Minimum Distance Classifier Technique. International Journal of Advanced Engineering Research and Science. Vol. 3, Issue 9, Sept. 2016. ISSN:2349-6495(P) / 2456-1908(O).
- Keunhwi Koo,Jong Pil Yun,Sung Hoo Choi, Jong Hyun Choi, Doo Chul Choi, Sang Woo Kim (2014): Character Segmentation and Recognition Algorithm of Text Region in Steel Images. Proceedings of the 8<sup>th</sup> WSEAS International conference on signal processing, robotics and automation.Avaliable @ [https://www.researchgate.net/publication/228896273\\_Character\\_segmentation\\_and\\_recognition\\_algorithm\\_of\\_text\\_region\\_in\\_steel\\_images](https://www.researchgate.net/publication/228896273_Character_segmentation_and_recognition_algorithm_of_text_region_in_steel_images)
- Khashman, A, and Sekeroglu, B. (2007): Global binarization of document images using a neural network 2007 proc. 3rd International IEEE Conference on signal-image Technologies and Internet-Based system, Shanghai, China, 16-18 December 2007, pp. 665-72.

- Kishan Chakraborty, Jordan Basumatary, Debasmita Dasgupta, Jagadish Chandra Kalita, Subra Mukherjee (2013): IJRET: International journal of research in engineering and technology. eISSN:2319-1163. Vol. 02, Issue: 11, November 2013, Available @ <http://www.ijret.org>
- Konstantinos Ntirogiannis, B. Gatos, I. Pratikakis (2012): combined approach for the Binarization of handwritten document image pattern recognition Letter, Elsevier.
- Konstantinos Nitrogiannis, Basilis Gatos and Ioannis Pratikakis (2013): Performance Evaluation Methodology for Historical Document Image Binarization. IEEE Transaction on image processing, Volume 22, No2, February 2013.
- Kohonen T (1989): Self-organizing and associative memory. Third edition, Springer Information Science Series, Springer – Verlag New York, NY.
- Kopstein J., Lichbach M. & Hanson S. E., (2014). Comparative politics: interests, identities, and institutions in a global order. Cambridge University Press. Available at: <https://books.google.co.uk?id=zXjsAwAAQBAJ&pg=PA52&dq=funding+the+militants+in+the+niger+delta+by+the+governors&source=>.
- Kuldeep Narayam Shukla, Anjali Potnis and Prashant Dwivedy (2017): A Review on Image Enhancement Techniques. International Journal of Engineering and Applied Computer Science, Vol. 02, Issue 07, ISBN:978-0-9957075-8-0, July 2017.
- Li W., Tian W., Cao X., Gao Z., (2010) Application of Support Vector Machine (SVM) on serial number identification of RMB. Proceedings of the 8th World Congress on Intelligent Control and Automation, Jiman, China, July 2010. Retrieved on 12/2/2019.
- Manjula, K.A (2015): Role of Image Segmentation in Digital Image Processing for Information processing. Int. Journal of computer science Trends & Lech – Vol. 3, Issue 3, May-June 2015. ISSN: 2347-8578.
- Masato Aoba, Tetsuo Kikuchi, Yoshiyasu Takefuji (2003): Euro banknote recognition system using a three layer perceptron and RBF networks. IPSJ Transaction on mathematical modeling and its application. Vol. 44, No SIG 7(TOM 8), May 2003.
- Mayank Parasher, Ashok Sharma, Shruti Sharma and Jai P. Gupta, (2011): Indian Journal of Computer Science and Engineering: Anatomy on Pattern Recognition. Available at [https://www.researchgate.net/publication/228721547\\_ANATOMY\\_ON\\_PATTERN\\_RECOGNITION](https://www.researchgate.net/publication/228721547_ANATOMY_ON_PATTERN_RECOGNITION)
- Mitchell, T.M (1997): Machine Learning. McGraw-Hill Science/Engineering/Math. Retrieved November 26, 2019
- M. Deborah and Soniya Prathap (2014): "Detection of Fake currency using Image Processing". IJISSET – International Journal of Innovative Science, Engineering and Technology, Vol. 1, Issued 10, 2014.
- M. Sezgin, B. Sankur (2004): Survey over image thresholding techniques and quantitative performance evaluation. Journal of Electronic Imaging 13 (1) (2004) 146-168.
- M. Tulin Yildirim, Alper Bas Turk and M. Emin Yuksel (2008): Impulse Noise Removal from Digital Images by a Detail- Preserving Filter Based on Type-2 Fuzzy Logic. IEEE Transactions on Fuzzy systems, pp 920-928, 2008.
- Mohammad Shorif Uddin, Pronaya Prosun Das, Md. Shamim Ahmed Roney (2016): Image-Based Approached for the Detection of Counterfeit Banknotes of Bangladesh. 5<sup>th</sup> international conference of Informatics, Electronics and Vision.

- Moghaddam, R.F., Cheriet, M.: Ad Otsu (2012): An adaptive and parameter less generalization of Otsu's method for document image binarization. *Pattern Recognition* 45(6), 2419-243 (2012).
- Muhammad Akbar, Awaluddin, Agung Sedayu, Aditya Putra, Setyawan Widyarto (2013): Original and Counterfeit Money Detection based on Edge Detection. 2013 International Conference on Instrumentation, Communication, Information Technology and Biomedical Engineering, November 7-8<sup>th</sup>, Bandung, Indonesia.
- Muhammad Safraz. (2015): An intelligent paper currency recognition system. *International Conference on Communication, Management and Information Technology (ICCMIT)* (2015).
- N. Patel & S.K. Dewangan, (2015): An overview of Face Recognition Schemes. *International Conference of advance Research and Innovation (ICARI-2015)*, Institution of Engineers (India, Delhi State Centre, Engineers Bhawan, New Delhi, India, 2015.
- Neha and Deepak, (2016): Improved Document Image Binarization using Hybrid Thresholding Method: A Review. *IJRST-International Journal for Innovative Research in Science & Technology*. Vol. 3, Issue 01, June 2016-ISSN (online): 2349-6010.
- Neetu Sharma, Kiran Narang (2017): A review paper on currency recognition system. *International journal for research in applied science and engineering technology*. Vol. 5, Issue V, May 2017, Issue:2321-9653, Available [www.ijraset.com](http://www.ijraset.com)
- Nur Hadisukmana, Adri Yudianto N. P. (2018): Paper money recognizer using feature descriptor. *Indonesian journal of electrical engineering and computer science*. Vol.12, No.1, October 2018, ISSN: 2502-4752, DOI: 10.11591/ijeecs.
- Paridhi Swaroop, Neelam Sharma, (2016): An Overview of various Template Matching methodologies in image processing. *International journal of computer applications* (0975-8887), vol. 153, No, 10, November 2016.
- Parker J.R., (2010): *Algorithms for Image Processing and Computer Vision*, published by John Wiley & Sons, 29 November 2010.
- Pavia, A.R.C. (2010): Image Representation, Sampling and quantization. Retrieved from <http://www.wci.utah.edu/warpaiva/Classes/UI-ece6962/image-representation-and-discritization.pdf> on 25<sup>th</sup> October 2019.
- Pawan Patidar, Manoj Gupta, Sumit Srivastava, Ashok Kumar Nagawat (2010): Image De-noising by various Filters for Different Noise. *International Journal of Computer Applications* (0975-8887), Vol.9, No. 4, November 2010.
- Phillips R., (2008): Cash handling in South AFRICA'S EVER Changing Landscape. *Security focus: The official Industry Journal for professional security practitioners*. Downloaded on 13/8/19.
- Poth Miklos (2020): Image Interpolation Techniques. Available at <http://uni-obuda.hu/conferences/sisy2004/Poth.pdf>. Downloaded March 21st 2018.
- Poonam and Er. Rajiv Kamboj (2014): Image Enhancement with Different Techniques and Aspects. *International Journal of Computer Science and Information Technologies*, Vol. 5(3), 2014, 4301-4303.
- Priyanka Sharma, Manavjeet Kaur (2013): Classification in Pattern Recognition: A Review. *International Journal of Advanced Research in Computer Science and Software Engineering*. Available online at: [www.ijarcsse.com](http://www.ijarcsse.com)

- Prajapati, A., Naik, S and MEHTA, (2012): Evaluation of Different Image Interpolation Algorithms. International Journal of Computer Applications, Vol. 58, No. 12, pp. 0975-8887.
- Prasanthi and Setty (2015): Indian Paper Currency Authentication System Using Image Processing.
- Puneet, Naresh Kumar Garg (2013): Binarization techniques used for grey scale images. International journal of computer application (0975-8887), vol. 71 – No. 1, June 2013.
- Qizhi Xu, Louisa Lam, Ching Y. Suen (2003): Automatic segmentation and recognition system for handwritten dataes on Canadian bank cheques. Proceeding of the 7<sup>th</sup> International Conference on Document Analysis and Recognition, Edinburgh, UK, August 2003, pp704-708.
- R. Muthukrishnan and M. Radha (2011): Edge Detection Techniques for image segmentation. International Journal of Computer Science & Information Technology, 2011,3(6), 259.
- Rajni and Anutam (2014): Image Denoising Techniques- An Overview. International Journal of Computer Applications (0975-8887). Vol. 86, No. 16, Jan. 2014.
- Rama Gaur (2017): Classifiers in Image Processing, International journal on future revolution in computer science and communication engineering, vol.3, issue 6, ISSN: 2454-4248, June 2017, available @ <http://www.ijfrcsce.org>.
- Rashmi S. (2015): Degraded Document Image Binarization Techniques International Journal of current Engineering & Technology, vol. 5, No. 6, Dec., 2015. E-ISSN 2277-4106, P-ISSN 2347-5161, Available at <http://inpressco.com/category/ijcet>.
- Rashmi Saini (2015): Document Image Binarization Techniques, Developments and Related issues: A review. International Journal of computer Applications (0975-8887), Volume 116-No 7, April 2015.
- Rumi Ghosh, Rakesh Khare (2013): A study on diverse recognition techniques for Indian currency note. International journal of engineering sciences and research technology 1443-1447, <http://www.ijesrt.com>
- R. Vishnu, Bini O. (2014): ‘ Principal component analysis on Indian Currency Recognition’. Proceeding of the 5<sup>th</sup> International Conference on Computer and Communication Technology, Allahabad, Indian, september 2014.
- R.E. Haralick, K. Shanmugam, I. Dinstein (1973): Textural Features for Image Classification, IEEE Transactions on system, Man and Cybernetics, Vol. SMC-3, No.6, Nov. 1973.
- R.C. Gonzalez and R.E. Woods (2002); Digital Image Processing 2<sup>nd</sup> edition, prentice Hall, 2002, pp.272-274
- Rumi Ghosh, Rakesh Khare (2013): “An elegant Neural Network based draw near for currency recognition”, JECET; June-August, 2013; Vol. 2, 876-882.
- Sandeep Kaur, Navdeep Singh (2014): Image Denoising Techniques: A Review. International Journal of Innovative Research in Computer and Communication Engineering. Vol. 2, Issue 6, June 2014. ISSN (Online): 2320-9801.
- Sergios Theodoridis, Konstantinos Koutroumbas (1982): Pattern Recognition, Elsevier (USA), 1982.
- Shailendra Jumar Dewangan, (2016): Importance and Applications of Digital Image Processing. International Journal of Computer Science and Engineering Technology



(IJCSSET) ISSN: 2229 -3345 Vol. 7 No. 07 July 2016.

- Shreyas Fadnavis (2014): Image Interpolation Techniques in Digital Image Processing: An Overview. Shreyas Fadnavis Int. Journal of Engineering Research and Applications. ISSN: 2248-9622, Vol. 4, Issue 10(part 1), October 2014, pp.70-73.
- Shyju,S. and Thamizharasi,A. (2016): Indian Currency Identification using image processing. International journal of advanced engineering management and science, vol. 2, Issue 5, May 2016, ISSN: 2454-1311.
- Sokratis, V., Kavallieraton, E., Paredes, R. and Sotiropoulos, K (2011). A Hybrid Binarization Technique for Document Images, Retained on 17th October, 2019 from <http://seamtyI.win.tue.nl/svavilis/fullfext.pdf>.
- Sorge Belongie, Chad Carson, Hayit Greenspan and Jitendra Malik (1998): Colour and Texture Based Image Segmentation using EM and its Application to Content-Based Image Retrieval. ICCV '98: Proceedings of the Sixth International Conference on Computer Vision. January 1998. Available at <https://dl.acm.org/doi/10.5555/938978.939161>.
- Sukhjinder Kaur (2015): Noise Types and Various Removal Techniques. International Journal of Advanced Research in Electronics and Communication Engineering, Vol. 4, Issue 2.
- Suruchi G. Dadgaonkar, Anjali A. Chandavale, Ashok M.Sapkal (2012): Survey of Methods for Character Recognition. International Journal of Engineering and Innovative Technology, Vol. 1, Issue 5, May 2012.
- S. Watanabe, Pattern Recognition (1985): Human and Mechanical, New York; Wiley, 1985.
- T.Acharya and P.S Tsai, (2007): Computational Foundations of Image Interpolation Algorithms, ACM Ubiquity Volume 8, 2007.
- Thibant Jullian, Vincent Nozick, Hugues Talbot (2015): Image Noise and Digital Image Forensics. IWDW, Oct. 2015, Tokyo,Japan, PP 3-13, 10.1007/973-3-319-31960-5-1. HAL-01510076.
- T. Ojala and M. Pietikainen (2004): Texture classification, Machine Vision and Media Processing University of Oulu, Finland. Available at [http://homepagas.inf.edrac.uk/rhf/CVonline/Local - COPIES/OJALA/texture.ltm/](http://homepagas.inf.edrac.uk/rhf/CVonline/Local-COPIES/OJALA/texture.ltm/). January 2004.
- Vaimin Raval, Lokesh Gagnani (2012): Introduction to image Restoration Methods of Image Restoration. International Journal of Advance Research in Computer Engineering and Technology, Vol. 1, Issue 10, December 2012.
- Venkata Ranga Rao Kommineni, Hemantha Kumar Kalluri (2019): Image Denoising Techniques. International Journal of Recent Technology and Engineering.ISSN: 2277- 3878, Vol. 7, Issue-554, February 2019.
- Vidhi Roy, Gangey Mishra, Rahul Mannadiar, Sushant Patil (2019): Fake currency detection using image processing. International journal of computer science and mobile computing. ISSN 2320-088X @ 2019, ijcsmc, available online at [www.ijcsmc.com](http://www.ijcsmc.com)
- Vladimir N. Vapnik (1995): The Nature of Statistical Learning Theory. New York: Springer – Yorlag, 1995, p.188. Available at <https://www://:statisticalsupportandresearch.files.wordpress.com/2017/15/vladimir-vapnik-the-nature-of-statistical-learning-springer>.
- Watanabe S. (1985): Pattern Recognition: Human and Mechanical. Wiley, New York, 1985.

- Wenhong Li, Wenjuan Tian, Xiyan Cao, ZHEN Gao (2010): Application of support vector machine (SVM) on serial number identification of RMB. Proceedings of the 8<sup>th</sup> World Congress on intelligent control and automation. Jinan, China, July 2010.
- W. Ohyama, A. Yamamoto, T. Wakabayashi and F. Kimura (2014): Improving Accuracy of printed character recognition using Hexagonal Zoning of Directional Histogram Features. In proceeding 22nd international conference on pattern recognition, pp 2697-2702, Stockholm, 2014.
- Yaojia Wang Siyuan Lin, Siyuan Lin (2012): A currency recognition system. International Journal of Engineering and Advanced Technology, February 2012, pp 2249-8958.
- Yarlagadda, R.K.R. (2010): Analog and Digital signal and systems by R.K Yalagadda available at [www.books.google.com.ng](http://www.books.google.com.ng) downloaded on 04/10/19. DOL: 10.1007/978-1-4419-0034-0-1@stronger screens + Bustriess Edina, LLC 2010.
- Yi Wang, Bin Fang and Li-Jun Lan (2012): Adaptive Binarization: A New Approach to License Plate Characters Segmentation. IEEE 2012, Proceedings of the 2012, International conference on Wavelet analysis and pattern recognition, Xian, 15-17 July, 2012.
- Yousef Hawwar and Ali Reza (2002): Spatially Adaptive Multiplicative Noise Image Denoising Technique. IEEE Transaction on Image Processing, December 2002, Vol. II, No. 12.
- Yu-Shan Fong, Carlos A, Pomalaza-Raez, Xiao-Hua Wang (1989): Comparison Study of Non-Linear Filters in Image Processing Applications. Available @ <http://www.researchgate.net/publication/2555948864>.
- Yu-Shiuan Tsai, Yi-Yu Hsieh, Chih-Hui Ho, Ya-Ching Chang, Yao-Yuan Chang, Heng-Jyun Lin, Han-Yang Wang, Yu-Chen Chou, Jen-Hui Chuang (2018): Rule-Based Optical Character Recognition for serial number on Renminbi Banknote. <https://doi.org/10.2352/ISSN.2470-1173.2018.13.ipas-308@2018>, society for imaging science and technology. 2010.pdf. downloaded on 7<sup>th</sup> December, 2019.
- [https://en.wikipedia.org/wiki/Currency-counting\\_machine](https://en.wikipedia.org/wiki/Currency-counting_machine) retrieved on 30/01/19
- [https://en.wikipedia.org/wiki/Radio-frequency\\_identification#cite\\_note-Angell-2](https://en.wikipedia.org/wiki/Radio-frequency_identification#cite_note-Angell-2)
- <https://www.legit.ng/1110055-features-nigerian-currency-notes-coins.html>
- <https://en.wikipedia.org/wiki/Nigeria> on 27/5/19
- [https://en.wikipedia.org/wiki/Nigerian\\_naira#cite\\_note-15](https://en.wikipedia.org/wiki/Nigerian_naira#cite_note-15) on 27/5/19
- <https://en.wikipedia.org/wiki/Pixel> downloaded on 10/04/2020
- <https://www.cbn.gov.ng/Currency/securityfeatures/SecurityFeatures.asp>
- [mathworks.com/help/image/what-is-image-filtering.html](https://mathworks.com/help/image/what-is-image-filtering.html) downloaded on 02/04/2020.
- <http://www.mahalakshmiengineeringcollege.com/pdf/ece/VIIsem/EC2029/UNIT%20I.pdf>