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Article *in* Kasetsart Journal - Natural Science · July 2020

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DEEP LEARNING FOR GENUINE NAIRA BANKNOTES

*[1]Ogbuju, E., [2]Usman, W. O., [3]Obilikwu, P. and [4]Yemi-Peters, V.
[1, 2, 4] Department of Computer Science, Federal University Lokoja, Kogi State, Nigeria
[3]Department of Mathematics and Computer Science, Benue State University, Makurdi, Nigeria.

ARTICLE INFO

Received: 18 February 2020
Accepted: 03 May 2020

Keywords:
Naira note, Currency note, Colab, Image recognition, Input image, Image processing and Faster- RCNN.

Corresponding author:
emeka.ogbuju@fulokoja.edu.ng

Abstract

Over the past few decades, as a result of great technological advancement, currency counterfeiting problems have become more and more serious across the world. Counterfeit notes are currently one of the biggest problems occurring in cash transactions in Nigeria. Therefore, issue of efficient differentiation of counterfeit bank notes from genuine ones via automatic machines has become important. In this work, it is our goal to develop a system that would help to detect counterfeit banknotes and contribute to curbing the menace of currency counterfeiting. To achieve this, we applied a deep learning approach using Faster Region Recurrent Neural Network (FRCNN) to develop a naira detection model in Google Colab. The model is designed to be implemented in a mobile application for fake naira currency recognition called Naira Real. The system was tested with four (4) higher denominations of ₦100, ₦200, ₦500 and ₦1000 currency notes. The result of the overall system returned is an accuracy of 99% for genuine ₦1000 note and fake ₦500 note; and 98% accuracy on both fake ₦1000 and ₦200 notes. The system is relevant to financial institutions, business owners and all citizens who deal with currency transactions on a daily basis.

1.0 Introduction

The currency banknotes used in Nigeria is called Naira with the sign '₦' attached before the amount/denomination it describes. It comes in eight (8) denominations: four (4) lower denominations of ₦5, ₦10, ₦20, and ₦50 all printed on a 130 x 72mm polymer substrate; and four (4) higher denominations of ₦100, ₦200, ₦500 and ₦1000 all printed on a 151 x 78mm paper substrate. Although the Naira banknotes and coins are printed and minted by the Nigerian Security Printing and Minting (NSPM) Plc., it is the official responsibility of the Central Bank of Nigeria (CBN) to inspect the security and quality standards of the production, issue the currency notes/coins to the deposit money banks and retrieve old ones for destruction following their clean note policy. The production process of the Naira banknotes imprints security features into the notes to ensure the distinction between a fake and genuine banknote through a simple touch and sight. There is a raised print which provides tactility, a security thread which looks unbroken with a light, but broken with normal sight, and 'CBN' in small lettering printed on both sides; and a black serial number which turns green under an ultraviolet light. There are other features like the watermark, the embossed portrait lettering, denominational numerals, etc [7].

Despite these special security features which are meticulously provided by the NSPM to curb circulation of fake currencies, there are still cases of banknotes counterfeiting in Nigeria. The advent of the color printing technology brings this to an increase. The CBN reported that there was 0.0014% or 14 counterfeit notes out of one million bank notes as at December 2016 [8]. Again, an independent opinion research in Nigeria called the NOI Polls reported that 19% of Nigerians have come in contact with fake currencies on a personal basis mostly while making a transaction in the market place [21]. Although culprit are being apprehended as shown in Vanguard [33] and Pm news Nigeria [24], it is our goal in this work to develop a system that would help to detect counterfeit banknotes thereby contributing to apprehending the culprits and ending the spread of counterfeit notes in the Country.

Currency counterfeiting is not only seen in Nigeria. It is a threat to many nations' economy. In 2015, the US Secret Service suppressed 145 counterfeit manufacturing plants, arrested 796 counterfeit criminals and seized $58 million in counterfeit currency [32]. In 2016, "six counterfeit plants were suppressed, eight counterfeit manufacturing presses seized and over 1,600 printing plates and negatives of varying denominations were found" [31]. It is being experienced in India [3] and indeed in many countries as presented in Table 1.0 in various magnitudes.

Table 1: Magnitude of most forged currencies

S/N	Country	Currency	Magnitude of fake currencies seized each year
1	China	Yuan	2014: 532 million yuan (equivalent to $85.6 million) 2017: 214 million yuan ($34 million, £24 million)
2	India	Rupee	2014 – 2015: 4.27 million counterfeit notes
3	UK	Pounds	2016: 347,000 counterfeit banknotes worth £7.5 million
5	US	Dollar	2015: $58 million in counterfeit currency 2016: $30 million in counterfeit currency

6	Europe	Euro	2015: 445,000 counterfeit euro banknotes 2016: 50,000 counterfeit euros banknotes
7	Mexico	Pesos	2015: 306,063 counterfeit bills amounting to 99.1 million pesos (equivalent to $5.4 million).

Adapted from [17] and [12]

While it may be a fact to say that money may never become counterfeit-proof [9], many countries are advancing security features of their currencies to achieve the goal of counterfeit detection. Even though the US Dollar is one of the most counterfeited currencies, it is also one of the most difficult to fake. Others include Kazakhstan, Mexico, Sweden and Hong Kong as recognized by the the International Association of Currency Affairs [14]. The use of technology in advancing the security features of currencies and detecting their genuineness is a vital approach in the fight against counterfeiting. Individuals had devised manual or traditional means of identifying fake banknotes in Nigeria. Wahab [35] enumerated five (5) ways of detecting fake naira currency as follows: (1). Check the texture to ensure it is not very soft and the image looks dull, (2). Feel the note with wet finger to determine if the colour would wash off, (3). Check the ribbon/thread to ensure it is very thick, (4). Use a mercury bulb to see the hidden features, and (5). Check the gold foil to ensure it does not peel off with a scratch. There are many problems encountered in detecting the authenticity of a naira currency using these traditional means/approaches. In fact, the result of using these untidy traditional approaches in the detection of fake naira currencies is always inaccurate, unreliable, and inefficient. The methods are expensive, time-consuming and prone to high errors. While common people find it difficult to access any source of currency detection and are unable to identify the real or original currency [25], corporate business owners, bankers and other elites who use currency in their cash transaction or works in currency exchange offices find it very tedious to detect the currencies by mere traditional approaches [25]. This is why the malpractice of fake currency is carried out openly in our economy. There is need of automation techniques with which currency identification process can be efficiently done [10]. Also, the rapid growth of modern banking services speed up this need for automatic currency detection and recognition system. It is with these backdrops that we propose the use of deep learning approach in this work to detect and recognize fake Naira currencies. The system would be able to detect fake naira currency quickly and correctly. In this work, recognition of paper currency notes with the help of digital image processing techniques is described. The characteristic features extraction is performed on the image of the currency and it is compared with the characteristic features of the genuine currency. The decision making is done by the designed model. The system consists of the eight steps of the image processing techniques in achieving its goal, which include; image acquisition, greyscale conversion, edge detection, feature extraction, image segmentation, comparisons of images and output (Li & Yue, 2017). The system is designed to detect the four (4) higher denominations of ₦100, ₦200, ₦500 and ₦1000 currency banknotes. The aim of this work was to provide a currency detection system that can recognize fake naira notes. The objectives are (1) to design a real-time currency detection/recognition

model using Faster Region Recurrent Neural Network (FRCNN) and (2) to develop a user-friendly mobile application for fake currency detection. The system would provide an accurate naira detection and recognition in real-time which is beneficial to the financial institutions across the country. The entire work describes an application of machine learning to forensics for currency detection. It centers on creating a model, testing the model and finally using this model on an android mobile application.

1.2 Review of Existing Literature

There have been different methods and algorithms applied in the design and development of currency recognition systems for different countries around the world. Some of them includes Bangladeshi currency recognition system using Negatively Correlated Neural Network [37]; Chinese currency recognition system based on binary pattern [36]; Chinese currency recognition by Neural Network based on local binary pattern [36]; Pakistani currency recognition system based on three-layer classification [26]; and also Naira currency recognition using Visual Basics and Microsoft Access RDMS, and Matlab [4, 22]. In the Image processing domain, different tools and approaches had been employed in the automatic recognition of different currency banknotes [20, 27]. For instance, [2] designed a system for automatic recognition of security features of Indian Rs.100 currency note. The system identifies fake note from the genuine ones. The approach employed in the design of the system consists of several components like image processing, edge detection, image segmentation and characteristics extraction, and comparing images. The Matlab software was used as was also used in [3] and [28]. A similar work on the Indian currency was described by [20, 34, and 29]. They showed the recognition and detection of paper currency with the help of digital image processing techniques where the image of the currency is compared with the characteristics of the genuine currency already stored in the database. Likewise, Almu and Muhammad [4] described a related approach implemented on Visual Basic and MS Access database to recognize Naira currencies at 77.7% accuracy. Sargano [26] developed an intelligent system for Pakistani banknotes using a three-layer classification. The system returned a 100% recognition rate on properly captured images up to 175 Pakistani banknotes with extracted features of the aspect ratio, a set of useful colour features, a binary pattern of lettering block, a binary pattern of see-through block, and a binary pattern of identification marks block. In another instance, fake coins were detected in [18]. Thakur and Kaur [30] described the commonly used methods and the digital image processing methods as the two methods for fake currency detection. The commonly used methods includes: see-through register, watermarking, fluorescence, security thread, intaglio printing, latent image, micro lettering, identification mark, and optically variable ink. The digital image processing method includes eight stages of image acquisition, pre-processing, grayscale conversion, edge detection, image segmentation, feature extraction, comparison and output [5]. Guo *et al.* [36] proposed the Local Binary Pattern (LBP) algorithm for paper currency recognition for the Chinese currency. The LBP is a type of visual description used for classification in computer vision, and it is a classic tool for texture description. Jose [15] introduced an android based currency recognition system for visually impaired persons [13]. The model built in the work

was majorly to support them and make it easier for them to get used to the currencies. Komal *et al.* [16] presented a currency recognition system that could be used in any part of the world in shops, banks counter and automated teller machines using four kinds of techniques: texture-based recognition techniques which provide the measure of properties such as smoothness, coarseness and regularity; pattern-based recognition techniques which are a classification of objects based on some set of images; colour based recognition techniques and currency localization techniques which is a mixed approach where the first currency note is an image.

The literature review had shown that different methods and algorithms were used to design and develop currency recognition systems for different countries around the world. However, none of the works reviewed (and not many to the best of our knowledge) had demonstrated the application of FRCNN proposed in this work for a near real time recognition system. Also, very few works had been done on the detection and recognition of the Naira currency notes using deep learning. Faster RCNN is one of the widely used object detection neural networks. It is also the basis for many derived networks for segmentation and 3D object detection. At conceptual level, Faster-RCNN is composed of three Neural Networks namely; Features Network, Region Proposal Network (RPN) and Detection Network. The feature network is usually a well-known pre-trained image classification network VGG minus a few last/top layers. The function of this network is to generate good features from images. The output of this network maintains the shape and structure of the original image. The RPN is usually a simple network with three convolutional layers. The purpose of RPN is to generate several bounding boxes called Region of Interests (ROIs) that has high probability of containing any object. The detection network sometimes also called the RCNN network takes input from both the feature network and RPN, and generate the final result. The architecture is shown in Figure 1.

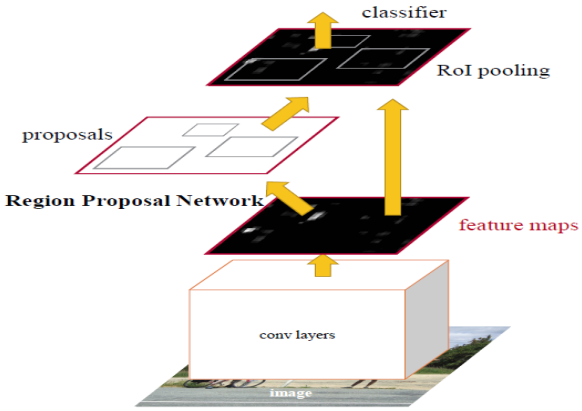

Figure 1: Basic architectures of Faster RCNN (Tsang, 2018)

2.0 Materials and methods

Classifying a currency note into genuine or fake is an ambiguity problem in the computer science domain. Ambiguity has been defined as an attempt to capture the intuition that an expression has multiple meanings. An expression is said to be ambiguous if it is capable of being understood or interpreted in two or more possible senses. An expression is used here in a generic way as to mean events, scenarios, and an object to mention a few. A court judgment that is being appealed is said to be ambiguous since it is being understood in a second sense other than the sense of the court judge who passed the judgment [6]. A court judgment in this context is an "expression". A currency note that can be either fake or genuine is capable of being understood in two different senses making it ambiguous. Ambiguity is quantified by the value of all context-dependent aspects of the

expression. The multiplicity of contextual values associated with an ambiguous "expression" creates a search space of alternatives [23]. The contextual values associated with a currency note are two, namely fake or genuine and the ambiguity problem to solve is to determine in any one scenario when a note is presented whether it is genuine or fake.

Ambiguity has been modelled as a non-deterministic Turing Machine (NDTM) [11]. A non-deterministic Turing Machine can be formally defined as a 6-tuple (Q, X, Σ, δ, q0,B, F) where: Q is a finite set of states, X is the tape alphabet, Σ is the input alphabet, q0 is the initial state, B is the blank symbol, F is the set of final states and δ is a transition function;

$\delta : Q \times X \rightarrow P(Q \times X \times \{Left\_shift, Right\_shift\})$.

That is, each output state P, is defined as a set of triples of the form $(q,b,\Delta) \in Q \times X \times \{-1,+1\}$, meaning that the machine reads X while in the input state from among Q and then changes its state to $q \in Q$, writes $b \in \Sigma$ to the tape, and moves the head by Δ. If P is empty, the machine moves to the reject state and halts. If P is non-empty and $q \in F$, the machine moves to the accept state.

Determining whether the bank note is genuine is proved to be an ambiguity problem when expressed as a non-deterministic Turing Machine as follows:

Let X be the properties of the notes that determines whether it is fake or genuine

q0 is the initial state and a set of properties, a $\in$ X is read

P = set of output states among which are

b1 $\in\Sigma$ = note is genuine

b2 $\in\Sigma$ = note is fake

the transition function, δ:

$q0 \times X \rightarrow P(q1 \times X \times \{Right\_shift\}) = \delta(q1, b1)$

$q0 \times X \rightarrow P(q2 \times X \times \{Right\_shift\}) = \delta(q2, b2)$

The automata reading the properties of a note has two options, goes to state q1 and outputs b1 meaning the note is genuine. In the second option, it goes to state q2 and outputs b2 meaning the note is fake. Each transition function, δ (qi, bi), I = 1, 2 represents an attempt by the automata to predict an output based on the properties of the note read. The properties of the notes are determinants. They determine the genuineness or otherwise of any bank note thereby resolving the ambiguity problem.

At implementation, several instances of the determinants are stored prior to execution of the transition functions. With the current state of technology, especially big data stores, the real problem is no longer the size of the instances of the determinants as it was in the early days of research into ambiguity. The challenge now is developing machine learning algorithms that learn effectively from the instances making it capable of predicting or identifying the correct alternative at a high level of accuracy. Using big data technologies, the instances stored can be as large as the data set we can find. Technology has also provided processor power that can handle data sets of big data size.

In this work, the naira note images are used as the dataset. Processing and analysing the notes are good example of big data requiring an object detection technique. The Faster-RCNN object detection model used in this research is a convolutional neural network with 24 convolutional neural networks and 2 fully connected layers making a total of 76

nodes all together on the network. The model was trained with 4 labeled classes in the following structure:

```
100 Naira: 120 images and annotations
200 Naira: 140 images and annotations
500 Naira: 135 images and annotations
1000 Naira: 335 images and annotations
```

Listing 1: Dataset structure

So in essence we have a total collection of 730 images of four (4) classes of naira currency notes (100, 200, 500 and 1000 naira) at different positions and different textures obtained through the use of Google Search tool and different phones cameras. The dataset is shown in Figure 2.

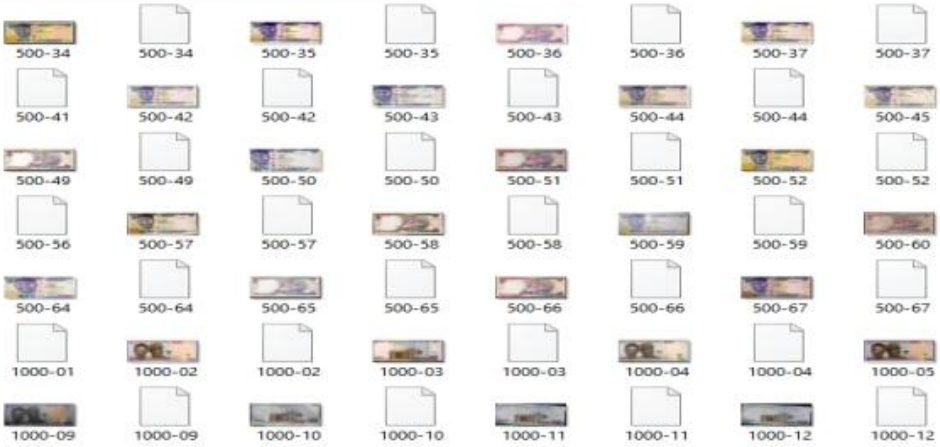

Figure 2: Datasets Collected

An .xml annotation was created for each class of naira currency to give their detailed descriptions like the position of the desired object in the image using boundary boxes.

Figure 3: Annotated Image

Google Collaborator (Colab) is used in the work to extract the basic features of the available naira currency. Colab is a free hosted Jupiter notebook environment that has no intricate setup requirements. It is a clouds service that offer or support free graphical processing unit (GPU). It is also a platform that offers popular libraries such as Keras, Tensorflow, PyTorch, and OpenCV without going through the hassle of installing them afresh. The Colab platform enabled us to load our locally curated datasets onto it through our Github account where they were stored. There are many key features on the naira currency such as the security thread, latent image, watermark, gold foils, and color which were taken into consideration for the classification problem. The Figure 4 demonstrates the key features extraction from a 1000 Naira note indicating the security thread, serial number, latent image, coat of arms, pyramid, gold foils, and others.

Figure 4: Feature extraction from 1000 naira note

Each of the dataset goes through the image processing steps (input, processing – gray scaling, features extraction, recognition and detection) to determine their genuineness. The extracted features are passed into the recognition and detection module where the Faster RCNN is employed for the task.

3.0 Result/Discussion

Having a goal to provide a solution for recognition and detection of fake naira currency, we designed a mobile app called NairaReal (₦Real) - (pronounced 'Real Naira'). The application has two basic features which include recognition and detection of fake naira currency in real-time. NairaReal is designed to solve the aforementioned problems during the detection of fake naira currency processes with three modules which include:

1. **Verification module:** Verification of users' data is an important aspect of the system which is achieved by a password security authentication technique. Successful user authentication and verification on the system promotes easy retrieval of relevant data on the system. A user is denied access when the wrong username and password are provided as input to the system.

2. **Recognition module:** This module is saddled with the responsibility of identifying whether the currency in question or under investigation is a naira currency or not. This module is very essential because we have numerous kinds of currencies in use. The system only recognizes Naira notes.

3. **Real-time detection:** This is the most important aspect of this system. The system detects the currency notes with a real-time inbuilt camera on the app installed on a handheld device (android mobile phone). The developed model is designed to be deployed in this module.

The app is shown is Figure 5.

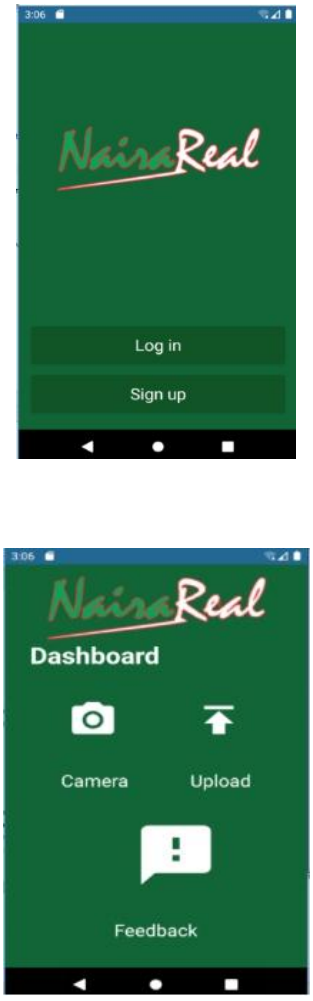

Figure 5: NairaReal Login and Dashboard

The system was tested with new sets of 200, 500 and 1000 naira notes and the result is shown in Figure 6.

Figure 6: Boundary box output on an image currency file with trained faster RCNN model

The model recognized the notes and detected them with the following accuracies:

a) Genuine 1000 Naira Note with 99% accuracy
b) Fake 1000 Naira Note with 98% accuracy
c) Fake 500 Naira Note with 99% accuracy
d) Fake 200 Naira Note with 98% accuracy

Advantages of the New System: NairaReal (₦Real)

1. It is a secure and reliable system for both bankers and general customers
2. It provides a real-time recognition and detection of fake naira currency notes
3. The system reduces challenges faced during the detection of fake naira banknotes
4. It speeds up the rate at which recognition and detection of fake currency note take place, hence, it saves time
5. It is interactive and user-friendly, providing a greater efficiency over the traditional methods

Some of the ill-effects that fake money has on society include a reduction in the value of genuine money; and an increase in prices due to money getting circulated in the economy; a decrease in the acceptability of paper currency [19]. This work had made a significant contribution to detect fake naira notes in the midst of the about ₦2.1billion genuine currency banknotes issued by CBN and currently in circulation in Nigeria [1]. Automatic techniques for paper currency recognition and detection systems become an important component to be taken into consideration for the growth of the economy of any country including Nigeria. Introducing and implementing information technology to the financial system and the

business world as a whole is a milestone in protecting the economic prosperity, enhancing growth and maintaining social harmony.

4.0 Conclusion

This work had been able to demonstrate the development of a real time detection model and show the design of a mobile app (NairaReal) for its deployment. The mobile app involves basic features like the authentication of users and the use of the app camera to capture the currency image. The deep learning object detection model trained and tested in this work is designed to be used on the app camera for object detection of images taken in real-time. This system is highly recommended to everyone, especially the banking sector and business owners, as a tool that can be used to distinguish between naira currency note which is easier and more accurate. The work is limited by the detection and recognition of only four (4) classes of naira currency notes (100, 200, 500 and 1000 naira). Our future work will be to incorporate the remaining four (4) lower denominations of ₦5, ₦10, ₦20, and ₦50 in the system and expand the scope to recognise and classify currency notes from other countries in Africa. Again, putting the accuracy into consideration, we intend to keep making gradual improvements to the object detection accuracy of the model by expanding the dataset up to about 10,000 currency images and training same on a GPU. Also, though the developed model and the app work well, the integration of both for end-users is still an ongoing work.

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