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DEVELOPMENT OF A CURRENCY RECOGNITION SYSTEM FOR NIGERIAN PAPER CURRENCY

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Abstract

Money is any instrument or item that is legally accepted as a means exchange for the procurement of goods and services and paper money is the Nigerian official currency used for transaction related purposes. The printing of paper currency is regulated by a country's central bank/treasury in order to keep the flow of funds in line with monetary policy. In identifying and recognizing Nigerian Naira currencies in Edo state during daily cash transactions, the most popular method used is by manually checking for specific features on each naira paper note. This is usually prone to errors as some of the security features on the naira note cannot easily be identified by the human eye. The Central Bank of Nigeria reported that the N1000, N500 notes are the most counterfeited of the Nigerian paper currencies. Also, N98.82m of fake banknotes were also reported to have been detected in 2018 and N1.89trn, fake mutilated naira notes destroyed by the Apex bank. Thus, this paper presents a currency recognition system that is designed to recognise and validate Nigerian paper currencies. The system is designed for the upper denomination of the Nigerian currencies. These are the N1000, N500, N200 and N100 notes respectively. Recognition of the different denominations involved the extractions of certain security features of the different denominations from a base currency of the denomination and extraction of similar features from the tests currency. The extracted features represent feature vectors of the Base and the test currency. The feature vectors are then compared for the base and the test currencies using Euclidean distance algorithm for similarity. Validation of the genuineness of the denominations is carried out by extracting and comparing vectors of statistical measures of textures vis-à-vis mean, standard deviation, energy, contrast, entropy for the base currency and the tests currency. Results shows that the developed system can conveniently be used for the recognition and validation of the different denomination when the extracted features are exactly similar using their relevant pixel values.

***Keywords*:** Image based processing, Cropping, MatLab, Currency, Euclidean distance

1. INTRODUCTION

The most common instrument that is legally accepted as a means of exchange of goods and services is money. Money comes in different form and the Nigerian currency comes in Paper notes. The Central Bank of Nigeria is the only authorize body to produce the Naira notes. Due to the difficulty in identifying the security features in the naira notes, some dishonest persons produce the counterfeited naira note. The Central Bank of Nigeria reported that the N500 and N1000 notes are the most commonly counterfeited banknotes and that these higher denominations account for 65.29% and 34.49% percent of the total

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counterfeited notes respectively discovered [1]. It was also reported by the CBN that a total of 119, 663 pieces of counterfeited notes with a nominal value of N98.82 million recorded in 2018. These statistics indicate an increase in the counterfeited notes when compared with118,126 pieces with a nominal value of N94.43 million recorded in the corresponding period in year 2017 [2]. According to [3] CBN reported that they destroyed a total of N1.89tn fake naira notes.

Thus, the need for an automatic recognition and authentication of paper currency is becoming increasingly necessary in the business world and more importantly in the money market. Automation of the banking and financial transaction process has made this increasingly important. Typical in such area of importance of automatic recognition of paper currency is in vending machines, Automated Teller machines and other systems that require the use of paper currency as input. Large sums of money have been lost by businesses due to the inability to recognise fake currency by the visual perception. This research work presents an object recognition technique in identifying N1000, N500, N200 and N100 Nigerian paper notes.

2. RELATED WORK

Several works have been done in the area of currency recognition by many researchers. Development and application of different algorithms in paper recognition system have been adopted by these researchers in carrying out their works. These have adopted principles and algorithms from the domain of image processing, object recognition, automation, Robotics e.t.c. Several recognition systems have been developed by researchers for different currencies for different countries. These include currency recognition system for Indian Rupee, American Dollar, Saudi Arabian Riyal, and New Zealand Dollar of different denominations [4-7]. But only a few recognition systems are available in literature for the Nigerian currency [8-10]. With the recent report by the Central bank of Nigeria [1-3], It is imperative to develop a system that cuts across the higher denominations of the Nigerian currency paper notes to put an end to the menace of fake naira notes.

The researchers in [4], implemented a currency recognition system for the identification the Australian Dollar (AUD), Indian Rupees (INR), Saudi Riyal (SAR), American Dollar (USD) and the Euro (EUR) currencies. The researchers developed an algorithm for the currencies and implemented it with MATLAB software. The work proposed the extraction of the features of the different currency using the cropping method. Detecting the boundaries of the currency and extracting the region of interest (ROI). The extracted features values are then compared with an ideal feature value which has been calculated for its recognition. Features that were utilized in the proposition for the comparison are dimension of the currencies, the aspect ratio, the hues, saturation and Vertical (HSV) of all the pixel of the notes and applied the Euclidean distance classifier to compare. This work has a limitation of not having been adapted for the Nigerian currency.

In [5], a currency recognition system using image processing and minimum distance classifier techniques for differentiating original Indian rupees from counterfeited rupees was presented. The methodology adopted in this work involves the extraction of the aspect ratio of the currency, the hue, the segmentation of the ID mark and latent image using digital image processing techniques. The segmented features are then processed and classified using the minimum distance classifier. Euclidean distance was used in the work for the classification. A limitation of this work is that Nigerian currency was not considered.

The Authors in [6], presented a two dimensional discrete wavelet transform approach to implement a currency recognition system for the Indian paper currency. The security feature extracted are the security thread, RBI print and the serial numbers of the paper currency. The proposed system proceeds by extracting the textural and the non-textural features of the currency. The textural features were extracted using the discrete wavelet transform, while the non-textural features extracted are the serial number and the colour of the paper note.

In [7], an intelligent currency recognition system for the Indian rupee using salient features such as watermark, amount watermark, optical strip, optical variable ink and latent image was proposed. The methodology involves the computation of the structural similarity index (SSIM) of comparison of the watermark and the amount watermark features in the currency and a referenced (ideal) image as one of the recognition element. The steps outlined in recognizing original Indian rupee from a counterfeited Indian rupee involves image acquisition, segmentation of the acquired image, histogram equalization, region props for image properties collection. The major limitation of the work is that it was only developed for the Indian Rupees.

3.0 METHODOLOGY

The input to a paper currency recognition system is the digitized notes and the output is the features of the paper currency with region of interest. The methodology adopted for this system is as presented in Figure 1:

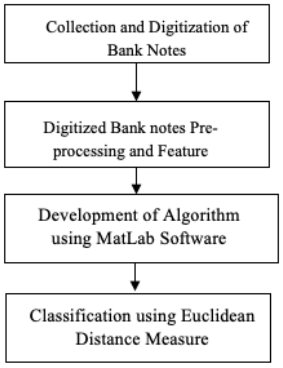

Figure 1: Research methodology for Paper Currency Recognition System

2.1. Collection and Digitization of Bank Notes:

The currency recognition system developed in this work is for the N1000, N500, N200 and N100 denominations of the Nigerian currencies. These notes were acquired and converted to a digital image by scanning using a 300dpi HP scanner with the scanned results as in Figures 2 and 3.

Figure 2: Front and back view of the N1000 and N500 Nigerian currency

Figure 3: Front and back view of the N200 and N100 Nigerian currency

2.2. Pre-processing and Feature extraction

The colour images of the currency were converted to the gray scale image format and the Numerical Inscription, the Portrait of statesmen on the currency, security thread which are the Region of Interests (ROI) were cropped out as in Figure 4. The cropped images are vectors of pixels representing the different features of the N1000 Nigerian currency. The different features were cropped for the different denominations that were involved in this research. This was done for the base and test currencies.

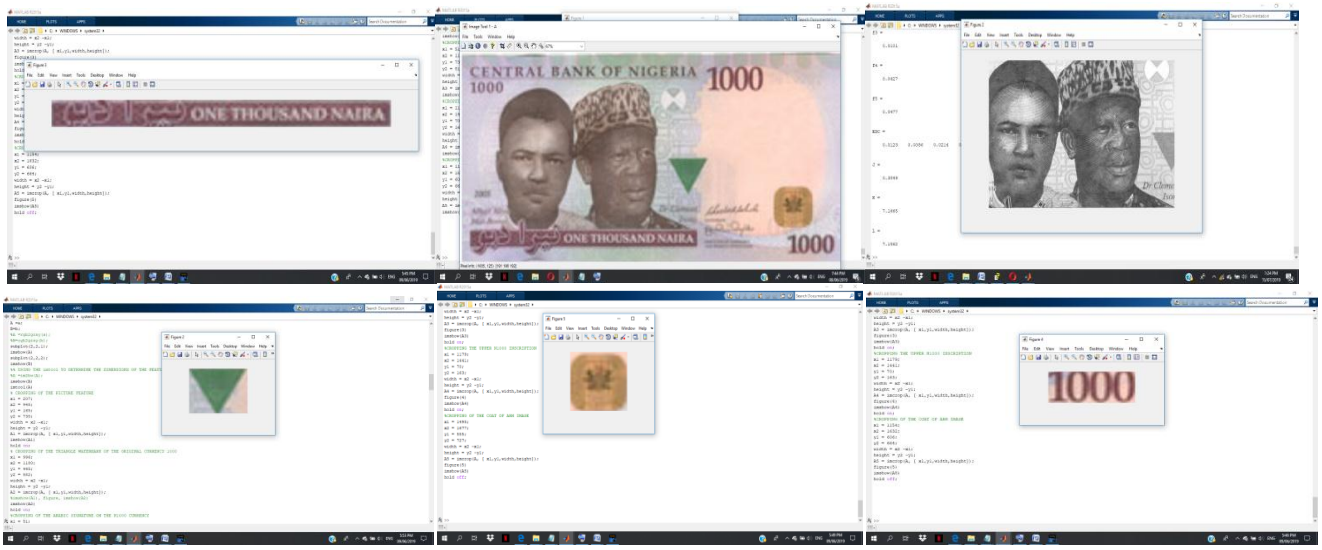

Figure 4: Cropped image vectors of pixels representing the different features of the N1000 Nigerian currency.

2.3. Development of Decision Making Algorithm

In this section, an algorithm was developed using MATLAB software that is used to compare if a given currency possesses the relevant features that indicates if it is an original or a counterfeited Nigerian currency. The algorithm was written taking into consideration the various classification and validation scheme as in section 3.4.

2.4. Classification and Validation Schemes

The feature vectors of the base and the test currencies were generated and the Euclidean distance algorithm was used to compare the corresponding vectors for similarity and the statistical measures of textures to validate the currency.

2.4.1. Euclidean Distance Scheme:

The feature vector of the base currency are of the form base = (a_1, a_2, a_3,……..a_n)^T and that of the test currency are of the form test= (b_1,b_2,b_3……..b_n)^T . The Euclidean Distance scheme for the comparison is given as:

Euclidean distance:dE $= \sqrt{\sum_{i=1}^{n}}$(ai − bi)^2 (1)

2.4.2. Statistical Measures of Textures:

There are several statistical measures of texture that exists. The statistical measures adopted for the validation of the different denominations after the recognition of the currency used in this research are the mean and the standard deviation as in equations (2) and (3)

Mean = m = $\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)$ (2)

Standard deviation = σ = $\sqrt{\sum_{J=0}^{L-1}(\mathrm{rj}-m)^{2\rho(\mathrm{rj})}}$ (3)

The following Texture based features were computed from a normalized gray-level co-occurrence matrix N_g (i,j) of the images:

Energy = $\sum_i \sum_j \mathrm{Ng}(i,j)$ (4)

Entropy = $-\sum_i \sum_j \mathrm{Ng}(i,j) \log_2 \mathrm{Ng}(i,j)$ (5)

Homogeneity = $\sum_i \sum_j \frac{\mathrm{Ng}(i,j)}{1+|i-j|}$ (6)

Correlation = $\frac{\sum_i \sum_j (i-\mu i)(j-\mu j)\mathrm{Ng}(i,j)}{\sigma i \sigma j}$ (7)

3. TESTS AND RESULTS

The paper currency recognition system developed in this work was implemented and tested for a database of 100 Nigerian paper notes. Tables 1 and 2 show the result of the Euclidean distance computation and statistical texture properties of the comparison of the base currency, tests currency and the fake currency to be recognized.

Table 1: Table of Euclidean Minimum Distance Measure

No.	Denomination		Full Image	Picture	Security Thread	Watermark	Numerical Value UPPER	Numerical Value LOWER
1.	N100	TEST 1	0.0402	0.0163	0.0400	0.0296	0.0197	0.0287
		TEST 2	0.0145	0.0100	0.0330	0.0397	0.0199	0.0415
		TEST 3	0.0512	0.0099	0.0598	0.0218	0.0194	0.0386
		TEST 4	0.0343	0.0089	0.0400	0.0250	0.0192	0.0406
		FAKE	0.1208	0.0638	0.0103	0.0831	0.0707	0.0929
			Full Image	Picture	Security Thread	Arabic Inscription	Numerical Value	Watermark
2	N200	TEST 1	0.0189	0.0075	0.0161	0.0147	0.0181	0.0432
		TEST 2	0.0219	0.0057	0.0275	0.0146	0.0167	0.0175
		TEST 3	0.0078	0.0061	0.0492	0.0148	0.0150	0.0173
		TEST 4	0.0160	0.0063	0.0278	0.0132	0.0150	0.0485
		FAKE	0.0534	0.0324	0.0430	0.0330	0.0598	0.1245
3	N500							
		TEST 1	0.0129	0.0037	0.0149	0.0128	0.0138	0.0596
		TEST 2	0.0099	0.0066	0.0162	0.0139	0.0229	0.0456
		TEST 3	0.0133	0.0035	0.0219	0.0134	0.0139	0.0831
		TEST 4	0.0099	0.0066	0.0137	0.0130	0.0226	0.0454
		FAKE	0.0931	0.0432	0.0602	0.0651	0.0944	0.01892
4	N1000							
		TEST 1	0.0063	0.0091	0.0340	0.0109	0.0298	0.0468
		TEST 2	0.0061	0.0037	0.0191	0.0106	0.0159	0.0301
		TEST 3	0.0167	0.0051	0.0186	0.0173	0.0367	0.0450
		TEST 4	0.0123	0.0086	0.0214	0.0101	0.0427	0.0477
		FAKE	0.0801	0.0597	0.1425	0.0929	0.1009	0.1517

Table 2: Table of statistical texture properties of the different currencies vis-à-vis Base, tests and fake currencies

No.	Denominations	Type	Mean M	Standard Deviation S	Entropy E	Homogeneity Ho	Contrast Co	Energy en
1	**N100**	BASE	213.7394	43.3050	6.5701	0.8354	0.7894	0.3037
		TEST 1	210.2710	43.8215	6.7006	0.8234	0.7954	0.2628
		TEST 2	211.9643	44.2660	6.6235	0.8344	0.8009	0.2915
		TEST 3	211.9706	43.4296	6.6294	0.8341	0.8015	0.2948
		TEST 4	211.0069	42.4153	6.5701	0.8396	0.7904	0.3046
		FAKE	184.9960	54.4669	7.2685	0.8544	0.9333	0.1398
2	N200	BASE	205.3937	46.5098	6.8657	0.8061	0.7847	0.2404
		TEST 1	206.3714	47.6305	6.8777	0.8108	0.7890	0.2597
		TEST 2	204.6311	46.9430	6.8987	0.8000	0.7858	0.2272
		TEST 3	206.5074	47.5769	6.8359	0.8131	0.7932	0.2628
		TEST 4	205.9254	46.5168	6.8874	0.8042	0.7798	0.2415
		FAKE	203.6358	43.1632	6.8595	0.8980	0.9394	0.2523
3	N500	BASE	205.5318	50.0049	6.8372	0.8036	0.7934	0.2543
		TEST 1	207.1725	49.2239	6.8144	0.8108	0.7994	0.2694
		TEST 2	206.0232	50.9767	6.8043	0.8123	0.8121	0.2712
		TEST 3	206.9361	49.6006	6.8251	0.8124	0.8037	0.2677
		TEST 4	204.5605	51.3282	6.8548	0.8063	0.8076	0.2581
		FAKE	182.6234	54.7914	7.3020	0.8655	0.9485	0.1342
4	N1000	BASE	187.1094	56.7049	7.1665	0.8218	0.9061	0.1524
		TEST 1	187.8167	56.1329	7.1813	0.8207	0.9020	0.1520
		TEST 2	187.8167	56.8066	7.1869	0.8149	0.8990	0.1515
		TEST 3	185.4387	57.7855	7.1726	0.8171	0.9037	0.1489
		TEST 4	188.1012	55.7972	7.1862	0.8199	0.9020	0.1501
		FAKE	179.9209	44.3397	7.1110	0.8787	0.9377	0.1395

4.1: Discussion

Table 1 is the result of the Euclidean distance computation of the comparisons of the cropped features of the base currency, test currency and fake currency for corresponding features. The similarity and eventual recognition of the currency and the denomination, is justified by the result of the comparison of the different features of the compared currency for the base and the test approximating to zero (0) with a margin of error of ±0.02, while the result for the fake currency has a wider margin of errors. From the results presented, the system worked satisfactorily in recognizing the currency because the values of the computations from the table were approximately zero. This computation is only able to recognize currency and not to authenticate the currency.The authentication of the currency was done using the statistical measures of texture of the currency. The values of these measures were compared with that of the base currency, test currency and fake currency for authentication subject to the margin of tolerance of deviation, which is cause by the limit of errors which are introduced by the cropping process as in Table 2 is presented in Table 3. The degree of the accuracy of the system to authenticate the currency is given in the Table 4.

Table 3: Measure of Accuracy of the Statistical Measures of Textures

Tests	Mean (e=±2.0)	Standard Deviation (e=±1.0)	Entropy (e=±0.02)	Homogeneity (e=±0.02)	Contrast (e=±0.02)	Energy (e=±0.02)
Tests 1-4 Original	93.75%	100%	100%	100%	100%	100%

Table 4: Measure of Accuracy of the System in Recognizing the Denominations

Tests	Error margin	Comments	Degree of accuracy
N100	0.05	Tests 3 FAILED, Tests 1,2,4 PASSED	75%
N200	0.05	Tests 1,2,3,4 PASSED	100%
N500	0.05	Tests 1,2,3,4 PASSED	100%
N1000	0.05	Tests 1,2,3,4 PASSED	100%

5.0. CONCLUSION

In this work, the development of a currency recognition system for Nigerian paper currencies capable of recognising counterfeited currencies of the N1000, N500, N200 and N100 denominations is presented. With the increase rate of counterfeit production of Nigerian currencies, this system can be adopted in tackling the menace of fake naira notes based on the Euclidean minimum distance measure and statistical texture properties values obtained.

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