A Framework for Verifying the Authenticity of Banknote on the Automated Teller Machine (ATM) Using Possibilistic C-Means Algorithm

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Abstract- With the introduction of cash-less society policy by the Central Bank of Nigeria, the Nigerian Banking sector over the years has been experiencing significant changes and development in its Information and Communication Technology (ICT). The degree at which bank customers are embracing e-banking services especially Automated Teller Machine (ATM) is increasing exponentially, which have helped in decongesting the banking halls. One worrisome issue associated with this development is that some ATMs are dispensing fake notes especially the higher denominations. This research proposes a framework that will assist in verifying the authenticity of the banknotes on the ATMs using segmentation of the extracted features from banknotes with Possibilistic c-means algorithm. Images of the banknotes will be acquired using a scanner or camera and the acquired image which will be in RGB will be converted to grayscale. The banknote will be denoised after which edge detection operation will be performed. Image segmentation operation will be performed through the PCM which will identity the features of the study banknote that are to be compared with those of the original pre-stored picture in the system. Marches in the banknotes features determine its genuinity.

Keyword – Possibilistic C-Means, ATM, Banknotes, E-Banking, Segmentation, Clustering, Framework

1. INTRODUCTION

Automated Teller Machines (ATMs) are devices that enable financial institutions clients to enjoy money transaction or banking services in public places without coming in-contact with bank cashiers or tellers. The modern ATMs, the customer is identified by inserting a ATM card, the ATM card is integrated with a chip that contains a unique card number and some data such as an expiration date, CVV (Card Value Verification) code and customer name[10]. ATM was introduced into the Nigerian economy by Central Bank of Nigeria (CBN) in 1989. The defunct Societe General Bank of Nigeria (SGBN) was the first commercial bank in Nigeria to introduce ATM in 1990. The trade name for SGBN’s ATM was "cash point 24"[5]. As part of banking reforms that started in July 2004, the Central Bank of Nigeria (CBN) in their quest to improve bank services, achieve cashless economy and decongest the banking halls, mandated commercial banks operating in Nigeria to install Automated Teller Machines (ATMs) in the bank premises and other strategic locations to serve their customers[4].

The introduction of ATM machines has undoubtedly marked a revolutionary change in the Banking sector by making money transactions a much easier and flexible task. However, the benefit of communication is accompanied with the concern for security. For an end to end security, it is thus not only sufficient to secure the network, but also imperative to consider threats which may exist because of the loop-holes existing in the computational systems[1]. [9] postulates that the level of ATM fraud tend to have overshadowed the improvements which it has brought into the service delivery systems of Nigerian financial institutions. Similarly [6] post that despite the reality that the introduction of ATM terminals as a banking instrument was lauded by several customers as an alternative to the frustrating queues that characterized the country’s banking hall, the situation today has changed drastically; it has become a source of worry to users and providers (banks) because the function it was meant to provide has been eroded seriously.
ATM uses are often subjected to cybercrimes and robberies & other crimes such as card and currency fraud, skimming attack, card trapping, logical/data attack, fake banknote issuance among others. Of all the aforementioned crimes, the crime that is yet to be widely acknowledged by our banking sector is the issuance of fake banknotes by these ATM. Verification and Authentication are very significant in any transaction; therefore, it is very pertinent for these security features to be included as an extra feature to be adopted to maintain transparency and accountability to the users.

The naira notes are protected by many security features to enable the recognition of genuine notes. The distinguishing features which can immediately be recognized by touch and visibility are raised print, the security thread and the watermark etc, as shown in fig 1 and 2. Other areas such as the portrait, lettering and the denominational numerals on the front and the back are embossed. The raised print provides the facility, while the security thread, which ordinarily, looks broken but is not when held against the light, has “CBN” in small lettering printed on both sides of the notes.

Section I contains the introduction of the research paper, section II contains the theory of the possibilistic c-means, section III contains the existing operation of ATM in Nigeria while section IV contains the the proposed method. Sections V and VI contain the conclusion and future work respectively.

![Figure 1: Security Features of the Front View of One Thousand Naira Banknote](image1)

![Figure 2: Security Features of the Back View of One Thousand Naira Banknote](image2)

2. THEORY OF POSSIBILISTIC C-MEANS

To overcome this limitation [8] suggest relaxing the column constraint \( \sum_{i=1}^{c} u_{ik} = 1, \forall k \), for fuzzy partitions so that \( u_{ik} \) better reflects what we expect for the typicality of \( x_k \) to the \( i_{th} \) cluster[7]. [8] proposed a new clustering model named possibilistic c-means (PCM)
\[ J_{PCM} = \sum_{k=1}^{n} \sum_{i=1}^{c} (t_{ik})^m \|x_k - v_i\|^2 + \sum_{i=1}^{c} \gamma_i \sum_{k=1}^{n} (1 - t_{ik})^m \]  

(4)

where \( \|x\|_A = \sqrt{x^T A x} \) and \( \gamma_i > 0 \) is a user defined constant, \( 1 \leq i \leq c \)

\[ t_{ik} \leq 1, \quad \gamma_i > 0 \quad \text{and} \quad \sum_{k=1}^{n} t_{ik} = 1 \forall i \]

\( x \) represents a data point

\( n \) is the number of data points

\( c \) is the number of clusters

\( \|x\|_A = \sqrt{x^T A x} \) is any inner product norm,

\( t_{ik} \) is given as the typicality of \( x_k \) in the \( i^{th} \) cluster

\[ t_{ik} = \frac{1}{1 + \left( \frac{D_{ik}^2}{\gamma_i} \right)^{1/(m-1)}} , \quad 1 \leq i \leq c, \quad 1 \leq k \leq n \]  

(5)

\[ v_i = \frac{\sum_{k=1}^{n} t_{ik} x^k}{\sum_{k=1}^{n} t_{ik}} , \quad 1 \leq i \leq c \]  

(6)

\[ \gamma_i = K \frac{\sum_{k=1}^{n} u_{ik}^m (x_k - v_i)^2}{\sum_{k=1}^{n} u_{ik}^m} \]  

(7)

The PCM algorithm assigns typicality value to fuzzy membership functions[8]. In this algorithm, the membership is interpreted as the compatibilities of the datum to the class prototypes(typicalities) which correspond to the intuitive concept of degree of belonging or compatibility in order words the membership value can be interpreted as the degree of compatibility (possibility)[7]. These typicality-based memberships automatically reduce the effect of noise and outliers through the optimization of the PCM objective function and improve the solution[8]. Thus, in PCM, the element of the partition matrix, denoted by \( t_{ik} \) instead of \( u_{ik} \)(1 \( \leq i \leq c, 1 \leq k \leq n \)), describe how compatible the input vectors are with the clusters represented by the computed cluster prototypes. Typicality values with respect to one cluster do not depend on any of the prototypes of the cluster[9]. Nevertheless, the main drawback with this approach as pointed out by [2] is that the price PCM pays to ignore noise point is that it is very sensitive to initializations. In the case of poor initializations, it is possible that the PCM will converge to a “worthless” partition where part or all the clusters are identical (coincident) while other clusters go undetected. This is referred to as coincident centroids and this failure is due to the reason that the membership degree depends only on the distance between the point to the cluster, and not on its relative distance to the clusters [8] as well as the lack of constraint placed on the typicality matrix.

3. EXISTING ATM SYSTEM OPERATION

An ATM system is a real-time front terminal of automatic teller services with the support of a central bank server and a centralized account database [11]. The existing system is simple to operate during the withdrawals of banknotes from the ATM with the following basic steps:

Step 1. User accesses his account using Debit (Master, Verve, Visa, etc.) card slotted through ATM machine and login to the system using valid PIN number.

Step 2. ATM machine reads this card and check it with Bank server.
Step 3. ATM awaits the user to enter the transactions request.

Step 4. The transactions page is displayed and by selecting the withdraw option and then enter the amount to withdraw.

Step 5. If the user has sufficient balance in their account, the cash is withdrawn. However, the machine is unable to detect whether notes are fake or originals.

4. PROPOSED SYSTEM

During the process of banknotes dispensation by the ATMs, fake notes are likely to be dispensed since the machines are not designed to verify these banknotes. In this paper a framework is proposed for the authentication of the banknotes to be dispensed by these machines. The proposed fake banknotes detection framework is implemented in the following phases.

a. Images of the banknotes will be acquired using a scanner or camera.
b. The acquired image in RGB will be converted to grayscale
c. The banknote will be denoised
d. Edge detection operation will be performed on the denoised image
e. Image segmentation operation will be performed through the PCM
f. The characteristic of study banknotes are compared with the original pre-stored picture in the system
g. If it matches, then the exchange is genuine otherwise counterfeit

4.1 Image Processing Phases

Image Acquisition: Image acquisition is the creation of digital images, typically from a physical scene. The image of a currency note is acquired by using digital camera. The image is then stored for further processing.

Image Pre-Processing: The aim of image pre-processing is to suppress undesired distortions or enhance some image features that are important for further processing or analysis.

Edge Detection: Aims at identifying points in digital image at which the image brightness changes sharply

Image Segmentation: This method sub divides the image into its constituent regions or objects. Segmentation algorithm for monochrome images generally are based on two properties

a) Discontinuity
b) Similarity

Feature Extraction: The aim is to analyze and identify the unique and distinguishing features of each denomination under various challenging conditions such as old notes, worn out notes, also under different illumination and background.

4.2 The PCM Image Segmentation Algorithm

Step 1: Initialize number of clusters c, weighting parameter m, termination tolerance \( \varepsilon > 0 \), typicality matrix \( T \) and estimate \( \gamma \) using equation 7
Step 2: Calculate the prototype of the centroid of cluster \( v_i \) where using equation 6
Step 3: Update by computing a new typicality matrix using equation 5
Step 4: Compare the membership matrices of the previous and after iteration. The iteration will stop if \( ||T^{(k+1)} - T^k|| < \varepsilon \), otherwise set \( T^k = T^{(k+1)} \) and go to Step 2
4.3. **Cash Dispense Procedure**

Step1. User accesses his account using Debit (Master, Verve, Visa, etc.) card slotted through ATM machine and login to the system using valid PIN number.

Step2. ATM machine reads this card and check it with Bank server.

Step3. ATM awaits the user to enter the transactions request.

Step4. The transactions page is displayed and by selecting the withdraw option and then enter the amount to withdraw.

Step5. If insufficient balance in the account, THEN step8

Step6. Perform authenticity of banknote

Step7. Dispense cash

Step8. Stop
Start

Insert Debit Card (Master, Verve, Visa, etc.)

ATM machine read & compare with bank server

User enter the transaction detail & amount to withdraw

If insufficient balance

Yes

Performed authenticity of banknote

Dispense cash

No

Stop

Figure 4: Program flowchart of proposed system
5. CONCLUSIONS
Interestingly people do not pay keen attention to the details and exact characteristics of banknotes for their recognition, rather they consider the common characteristics of banknotes such as the size, the background colour (the basic colour), and texture present on the banknotes. These characteristics are not enough to determine if a banknote is counterfeit or not. Each banknote denomination is made up of salient features which are unique and distinct to identify each one.

The framework described in this paper if implemented will make the banking process a trustworthy and reliable process. With this proposed framework fake banknotes can be eliminated completely from the market and banks can provide the best quality services to customers.

6. FUTURE WORK
The PCM algorithm works well on most noise images, nevertheless, the main drawback with this approach as pointed out by [2] is that the price PCM pays to ignore noise point is that it is very sensitive to initializations. In such situation, it is possible that the PCM will converge to a “worthless” partition where part or all the clusters are coincident while other clusters go undetected(coincident centroids). Future research could focus on using PFCM (Possibilistic Fuzzy C-Means) algorithm which is a good classification test because it possesses the capabilities to give more importance to typicality or membership values to authenticate the banknotes much faster. The model also relaxes the constraint (row sum =1) on the typicality values but retain the column constraint on the membership values in order to achieve the significant robustness against noisy data and outliers presence which is a very important detail to consider in bank notes.

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