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Banknote Authentication using Random Forest Classifier

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Abstract – **Financial institutions have adopted various automated banking systems using currency recognition as their main activity, which makes automated currency recognition of significant interest. It is difficult for humans to tell true and fake banknotes apart especially because they have a lot of similar features. Fake notes are created with precision, hence there is need for an efficient algorithm which accurately predicts whether a banknote is genuine or not. This paper proposes machine learning techniques to evaluate authentication of banknotes. A supervised classification algorithm, random forest classifier is used for differentiating genuine banknotes from fake ones. The performance of proposed research work is evaluated using certain evaluation parameters; accuracy, sensitivity and precision.**

Keywords – **ATM, Banknote, BRBNMPL, Data mining, Random Forest Classifier.**

I. INTRODUCTION

Currency started serving as a medium for exchanging goods and services thousands of years ago to replace the ancient barter system where any objects could be swapped if two traders agreed [1]. Even nowadays, currency, as a measurement unit in pricing a transaction, still plays an indispensable role in modern society. For example, it is used as a medium of payment in tackling debt, and as a store of value for savings [2]. The monetary form has been extended to cash including coins and banknotes, cashless money like bank cheques, and even electronic data representing currency in bank accounts.

Banknotes can be traced back to the year 1023 when they officially appeared in China for the first time in history, called "jiaozi", and were later introduced by American colonists for systematic use in the western world [1] [2]. In spite of its long history, the worldwide market for banknote printing is still fairly confidential, which is typically justified as the intention of protecting the secure surroundings for the production of this unique product. The printing apparatus and the security inks, as well as the completely automated machinery for excellent accuracy of banknote examination or the highly secure shredding equipment for used notes are not familiar to the general public.

With little revelation of the techniques for the production of banknotes, nevertheless, there is an enormous amount of research starting to reveal the inside story of the banknote, especially in the field of banknote recognition. Nowadays, numerous paper currency recognition systems have been developed through secure analysis, and have had a wide range of applications, such as automated teller machines (ATMs), banknote sorting machines, self-service payment kiosks, and portable devices assisting the visually impaired with recognising banknotes.

Banknote recognition mainly concerns the process of identifying the denomination of a banknote, particularly when a single currency is to be studied [3]. In essence, it is the process of classifying the banknote to one of the classes it belongs to [4]. Unlike coins minted by heavy metals, almost all the banknotes worldwide are produced to be as thin as ordinary paper [5]. The newly released Series 7 New Zealand banknotes are a typical example. They are printed on paper polymer, which is a type of polypropylene plastic, enabling them to be lightweight [6]. If weighing coins could be a straightforward way to distinguish different denominations of coins, then apparently, weighing banknotes is not a feasible way to distinguish different denominations of banknotes, due to the intrinsic lightweight property of the raw material. Even so, many other distinctive characteristics of banknotes allow them to be validated and classified by various methods. Those features could be grouped together by their accessibility levels. Level 1 contains the features that can be detected by human sense, such as substrate fidelity, print fidelity, colour fidelity, acoustic fidelity, serial number, holograms, watermark, security thread, security fibre, tactile fidelity, colour-shifting ink, clear window or latent image; Level 2 contains the features that can be detected by minor manipulation, such as micro-text or invisible glowing ink; Level 3 contains the features that could be detected by security analysis, such as magnetic ink, screen traps, manufacture

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anomalies, materials interaction, intricate patterns, intricate design, or fluorescence eminence [7].

II. Analysis of Banknotes in the World

The importance of knowing in depth the quality and performance of banknotes has gained ground worldwide in recent years, as more and more central banks are interested in analyzing their product and manufacturing process, in order to evaluate the substrate on which They print their current tickets and test new alternatives, always looking for the care of the environment, sustainability and quality in their processes, as well as welfare and social health. Due to the growing interest of companies and industries in environmental care and the investigation of new techniques that facilitate cleaner, sustainable and responsible production, in recent years life cycle analysis has gained an important worldwide presence in countless themes and applications; One of them and the one of greatest interest in the present study is the life cycle analysis of banknotes worldwide. In several countries a study has been carried out to know and thoroughly analyze the production process they are currently carrying out, as well as to facilitate corporate decision making. Among the most representative studies are those conducted by the Reserve Bank of Australia [8], the National Bank of Switzerland [9], the European Central Bank [10], the National Bank of Canada [11] and the Central Bank of England [12], all of them with different objectives, but based on the regulations established by ISO 14040. It should be noted that the comparison between the results of these studies are not considered convenient since each of them incorporates different functional units, which makes it difficult to directly compare the Impact assessment obtained.

The Bharatiya Reserve Bank Note Mudran Private Limited (BRBNMPL) established by the Reserve Bank of India conducted a life cycle analysis, which only has the following results: The carbon footprint caused by cotton-based bills could be reduced in 3.5 times with the implementation of the polymer substrate. Polymer banknotes generate 10.5 times less impact on human health than that generated by the cotton banknote. The replacement of cotton fiber-based paper with the polymer substrate can reduce the energy consumption produced by non-renewable sources by about 3.5 times. The analysis indicates that the use of polymer banknotes is 4.5 times more environmentally efficient than the cotton fiber substrate [13].

The protection of banknotes is based on a range of high-tech security signs designed to protect them against counterfeiting. There is a race between ticket designers, which include new signs in the banknotes, and counterfeiters, who try to imitate these signs. Counterfeit notes are frequently sold in shops, usually by buying low-value items with relatively high-value counterfeits, in order to receive back as many authentic currency signs as possible. Many counterfeits are detected only when they reach the banks, i.e. after causing a financial loss to those who accepted them. This effect could be minimized, or completely avoided, if merchants carefully checked all tickets received from their customers. If several signs are carefully checked, it increases the chances of detection of counterfeits and the risks taken by the one who intentionally seeks to sell a counterfeit ticket.

The validation of banknotes is a difficult task also for people without visualization difficulties; under visible light the Banknotes copying are typically equal to authorized ones. Consumer authentication can be very beneficial in exceeding this issue. This fact makes scientists to develop several forgery discovery algorithms, taking into account various currencies.

III. Data Mining

Data mining is defined as the process of analyzing data from different perspectives in order to find unknown trends and patterns in them and converting them to useful information. Data mining is not a new idea, it has been widely used by financial institutions for credit scoring, fraud detection, etc.; marketers for direct marketing and cross-selling; manufacturers for quality control and maintenance schedule; as well as hospitals [14].

IV. Proposed Methodology

A. Dataset Description

Banknote authentication dataset used in this work is taken from center for machine learning and intelligent systems, this data were mined from images that were taken for the estimation of verification process for banknotes.

Attribute description: [15]

- Variance of Wavelet Transformed image (continuous)
- Skewness of Wavelet Transformed image (continuous)
- Curtosis of Wavelet Transformed image (continuous)
- Entropy of image (continuous)
- Class (integer)

B. Classification using Random Forest Classifier

It is based on a heuristic division of the description space. The construction of the decision structure of

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a tree is carried out by recursive partitioning of this space, which makes the final decisions strongly dependent on the upstream divisions. The search space of the possible decision tree structures is then strongly restricted by these dependencies.

In order to understand random forests, it is interesting to start by giving the definition of Leo Breiman in his article published in 2001 in the international journal Machine Learning. Here is a literal translation [16]:

Definition: A Random Forest is a classifier comprising a set of elementary classifiers of the decision tree type, noted:

$$\{h(x,\Theta_k),\ k = 1, \ldots L\} \quad (1)$$

Random forests were introduced by Breiman (2001) by the following very general definition [16]:

Let $\left(\hat{h}(\Theta_1), \ldots, \hat{h}(\Theta_q)\right)$ a collection of tree predictors, with $\Theta_1, \ldots, \Theta_q$ random variables independent of $\mathcal{L}_n$. The predictor of random forests $\hat{h}_{RF}$ is obtained is aggregating this collection of random trees as follows:

- $\hat{h}_{RF}(x) = \frac{1}{q}\sum_{l=1}^{q} \hat{h}(x,\Theta_l)$ Average of individual tree predictions in regression.
- $\hat{h}_{RF}(x) = \arg\max_{1\le k\le K} \sum_{l=1}^{q} 1_{\hat{h}(x,\Theta_l)=k}$ Majority vote among individual predictions trees in classification.

The term random forest comes from the fact that individual predictors are, here, explicitly predictors per tree, and that each tree depends on an additional random variable (that is, in addition to $\mathcal{L}_n$).

V. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

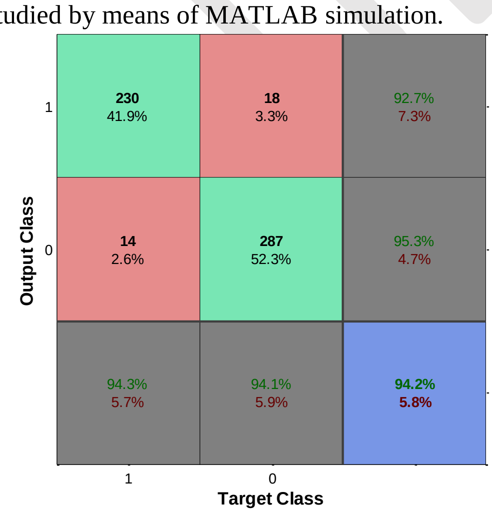

Figure 1: Confusion matrix plot for proposed banknote authentication using random forest classifier with 60-40 ratio (60 % training and 40 % testing)

Here, TP=230, TN=287, FP=18 and FN=14

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} = \frac{230+287}{230+287+18+14} = 94.2\%$$

$$Precision = \frac{TP}{TP+FP} = \frac{230}{230+18} = 92.7\%$$

$$Sensitivity = \frac{TP}{TP+FN} = \frac{230}{230+14} = 94.3\%$$

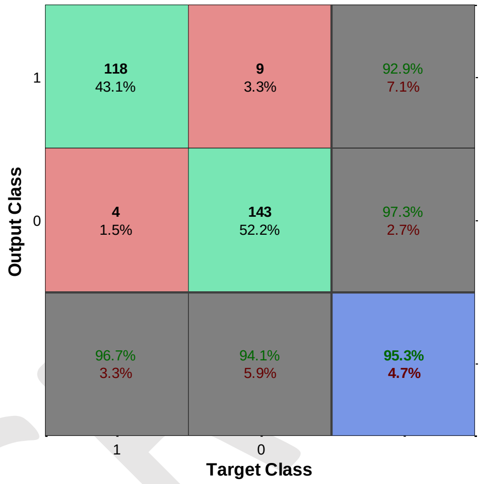

Figure 2: Confusion matrix plot for proposed banknote authentication using random forest classifier with 80-20 ratio (80 % training and 20 % testing)

Here, TP=118, TN=143, FP=9 and FN=4

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} = \frac{118+143}{118+143+9+4} = 95.3\%$$

$$Precision = \frac{TP}{TP+FP} = \frac{118}{118+9} = 92.9\%$$

$$Sensitivity = \frac{TP}{TP+FN} = \frac{118}{118+4} = 96.7\%$$

VI. Conclusion

After analyzing various techniques used to detect forged banknotes, this paper presents banknote authentication for recognizing the banknote as genuine or fake by using a supervised learning technique. Extensive experiments have been performed on banknotes dataset using the proposed model to find the best classification results. The result shows that 80-20 ratio case outperforms 60-40 ratio and gives 95.3% success rate. This technique is an efficient way of solving the problem for all banking-machines that accept all types of notes. In future, this work can be extended by categorizing the notes into different categories as Genuine, Low Quality forgery and High Quality forgery.

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