Statistical Techniques to Detect Counterfeit Indian Currency

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Abstract— Counterfeit Currency has numerous adverse effects to Indian Economy. Despite the safety features built into currency bills, there are no structured techniques to detect counterfeit currency other than visual inspection by experts. This paper presents various Digital Image Processing based techniques to reliably detect counterfeit currency [1].The algorithms rely on statistical nature of safety features, their histogram correlation Simulated Annealing is used to register the signatures of Bill under Test to Golden Standard. A real time detection is possible through the use of parallel processing feature using Graphic Processing Unit. The method is generalized and can be used for new class of currency bills released by Reserve Bank of India in denomination of 200, 500 and 2000. The algorithms are generic and can be applied to any world currency.

Index Terms— Digital Signal Processing, Geometric and Photometric Detection, Real Time Signal Processing, Karhunen- Loeve Transform (KLT), Simulated Annealing, Graphic Processing Unit (GPU)

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1 INTRODUCTION

Counterfeit currency is a major problem to the economies of the world. Imitation of banknotes produced by Reserve Banks of the countries is known as Counterfeiting of currency [2]. It is a loss to businesses and individuals as the confiscated bills by the law enforcement agencies are not reimbursed in any fashion. The Reserve Banks lose control on inflation and devaluation of currency. Liquidity of banknotes in economy leads to various other forms of financial disturbances. Indirect effects include holding in form of precious metals like gold by the public and businesses causing artificial hike in gold prices.

Anti-counterfeiting measures include detailed features in the print in form of special signatures, raised printing using Intaglio Ink, watermarks, use of special paper and plastic paper, embedded threads [3] etc. Color copying and printing technologies are available in open market to print counterfeit banknotes not detectable to human eye. Figure 1 shows genuine banknotes and counterfeit banknotes mixed randomly. The differences are imperceptible to naked eye. The issue is compounded in complexity when the situation occurs in real world like at gas stations, markets and shopping outlets. Banks have counterfeit currency detectors that use special scanning techniques and proprietary algorithms to detect counterfeit currency [4]. A cheaper reliable alternative is desired without use of special equipment. This paper is focused on comparing counterfeit banknotes and genuine currency based on various Digital Image Processing Techniques.

The class of Digital Image Processing techniques range from Geometric techniques to Photometric Techniques. A general purpose computer is capable of performing this analysis but a special processor with Graphic Processing unit can perform real time detection.

The code has been developed in MATLAB but a standalone executable can be generated to run faster on any OS and processor system. The scanned banknotes can rotate Simulated Annealing algorithm aligns the signatures perfectly and crops

Figure 1: Genuine and counterfeit banknotes

them to proper size for optimum detection.

The analysis is done in Red, Blue and Green spectrum exploiting the differences in printer resolution and color combination of printer available in open market and equipment used in Indian Currency [6]. The counterfeit banknotes were generated by scanning genuine banknotes on Canon LiDE 110 flatbed scanner at 2400 x 4800 dpi resolution with 48-bit color. The printout was done using Canon Pixma 2000 Color Printer

at 1200 x 4800 dpi on a Xerox Paper in photo quality mode. The counterfeit currency was destroyed after scan.

2 METHODOLOGY

The process involves generating a Gold Standard by high resolution scanning of genuine Rs 2000 banknote. The signatures are cropped and a compliance matrix is generated using MATLAB algorithm. Cropped regions also provide a template as initial guess for signature location to Simulated Annealing Algorithm. The algorithm is based on following correlation and alignment along principal axis using KLT. Figure 2 shows the flow chart of the various steps involved in detection.

Figure 2: Stepwise Methodology

Various statistical, geometric and photometric matric used in the algorithm are

1. Mean
2. Median
3. Mode
4. Correlation Coefficient
5. Histogram Correlation Coefficient

Golden Standard is generated using only one genuine banknote. A different genuine banknote and a counterfeit banknote are used as test cases.

3 SYSTEM DESIGN AND IMPLEMENTATION

Case of Counterfeit banknote as test input is used to explain the implementation. For alignment, rotation is carried out using KLT on gray scale image along the direction of Eigen Vector. Pan of mask of each signature is carried out individually to the point of optimum 2D Correlation.
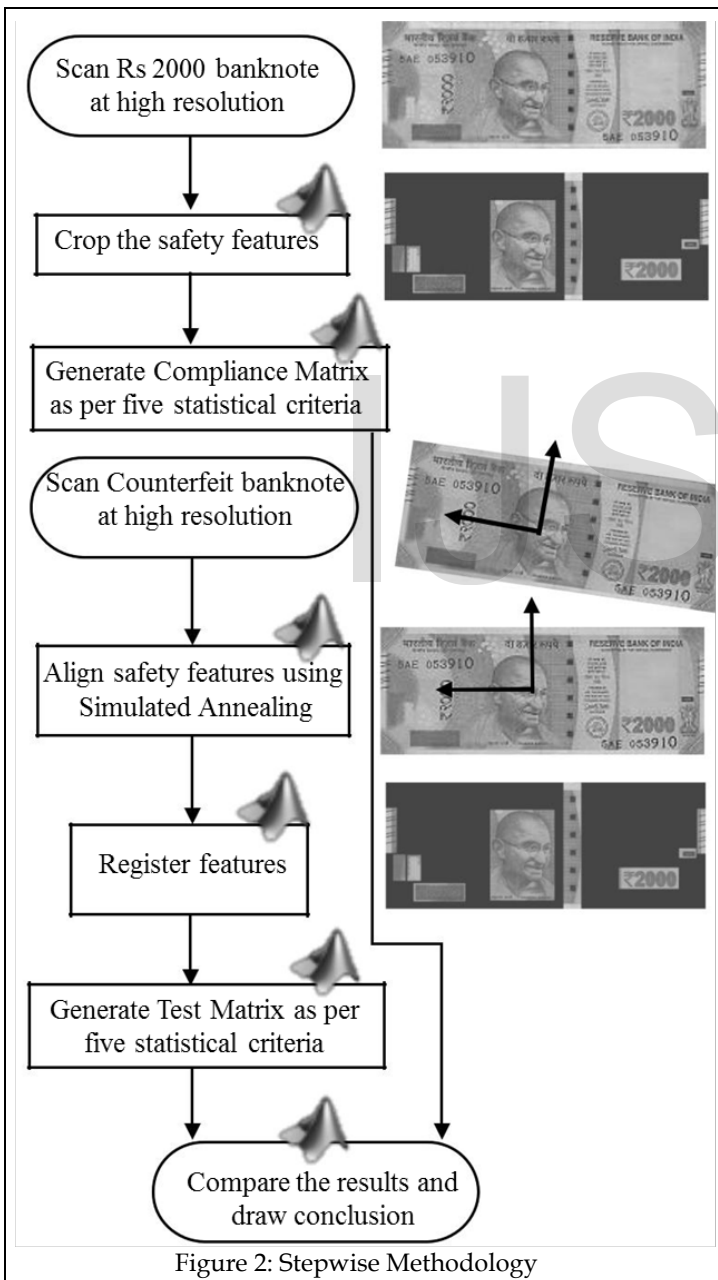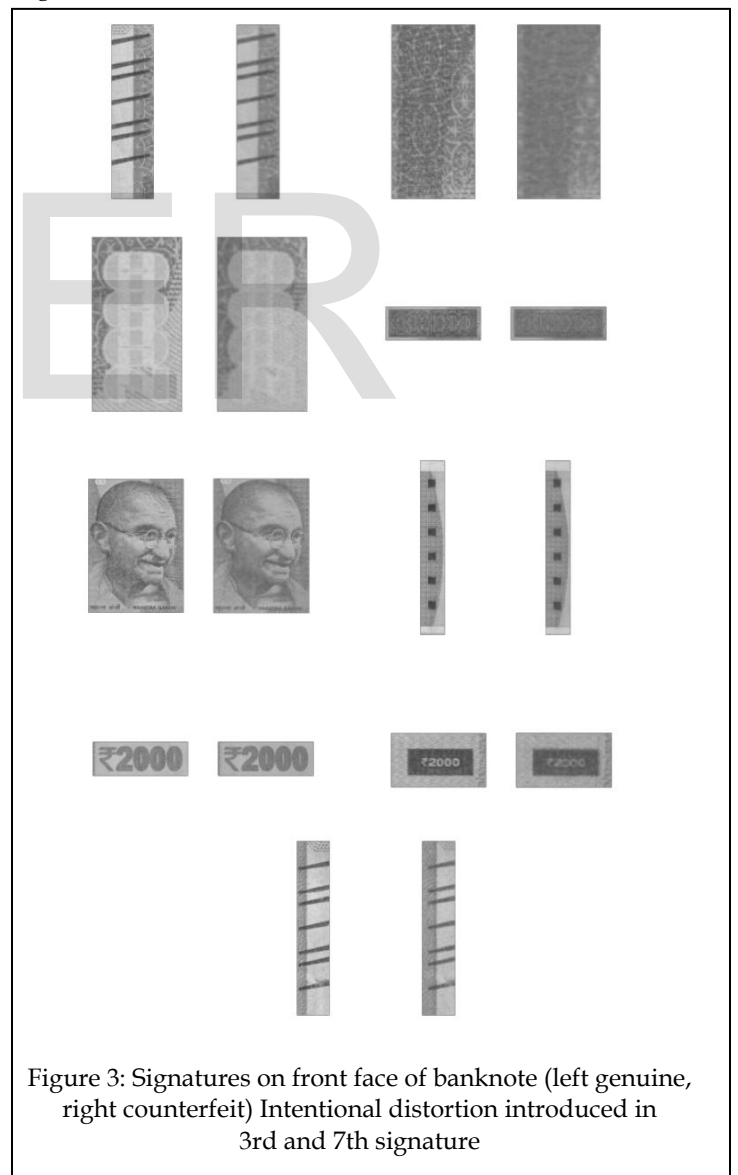Figure 3 shows the aligned signature of counterfeit banknote to golden standard.

Figure 3: Signatures on front face of banknote (left genuine, right counterfeit) Intentional distortion introduced in 3rd and 7th signature

Intentional distortion introduced in 3rd and 7th signature to test the algorithm. Mean, median, mode, histogram correlation is computed using column vector of signature for Red, Green and Blue colors. 2D correlation is carried out for Red, Green, and Blue colors. The analysis is repeated on genuine banknote different from Golden Standard.

4 RESULTS AND DISCUSSION

We start with comparing signatures in Red Component. Figure 4 shows mean for Golden Standard, Counterfeit note and genuine note.
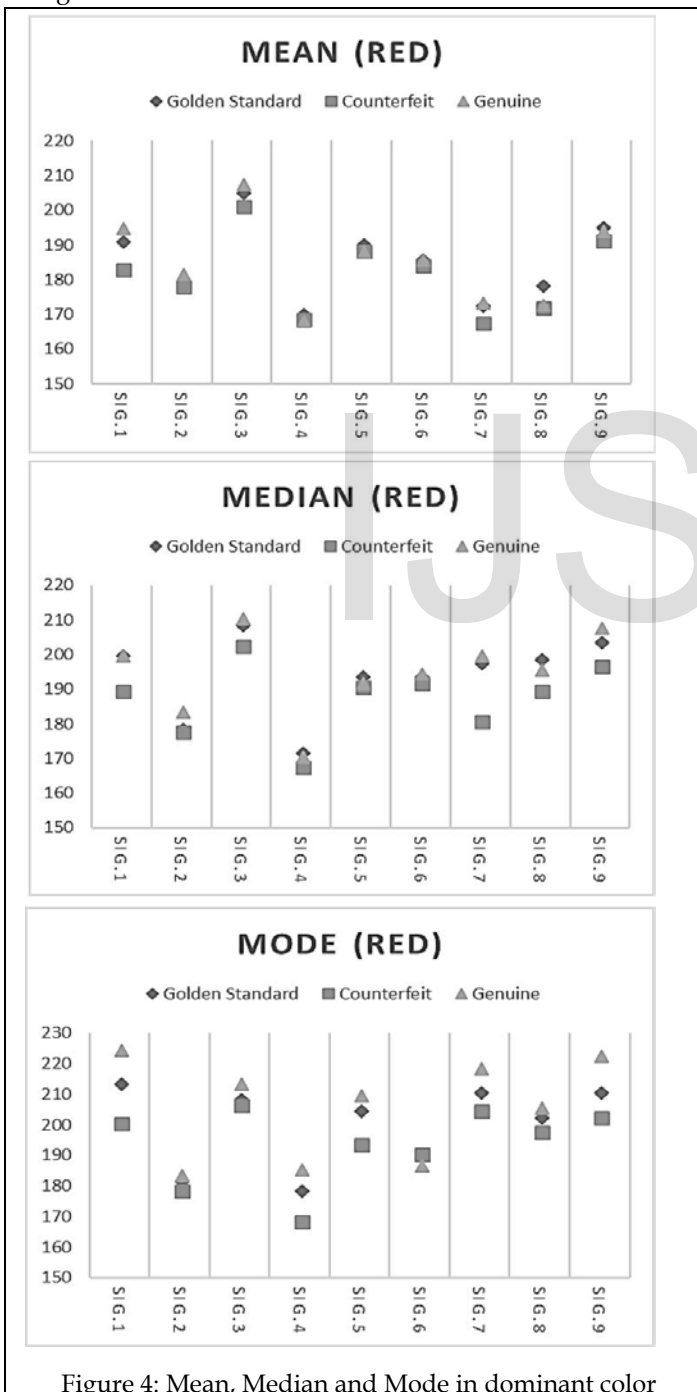

Figure 4: Mean, Median and Mode in dominant color

Counterfeit Banknote. In Green Component, Mean, Median and Mode of Genuine Banknote is closer to Golden Standard than the Counterfeit Banknote. In Blue Component, Mean, Median and Mode is conclusive evidence between Counterfeit Banknote and Genuine Bank Note. One of the non-dominant color component mismatch in terms of mean, median and mode is indicative of printer used different from the equipment used in Indian Currency. Figure 5 shows mean, median and mode in Blue color.
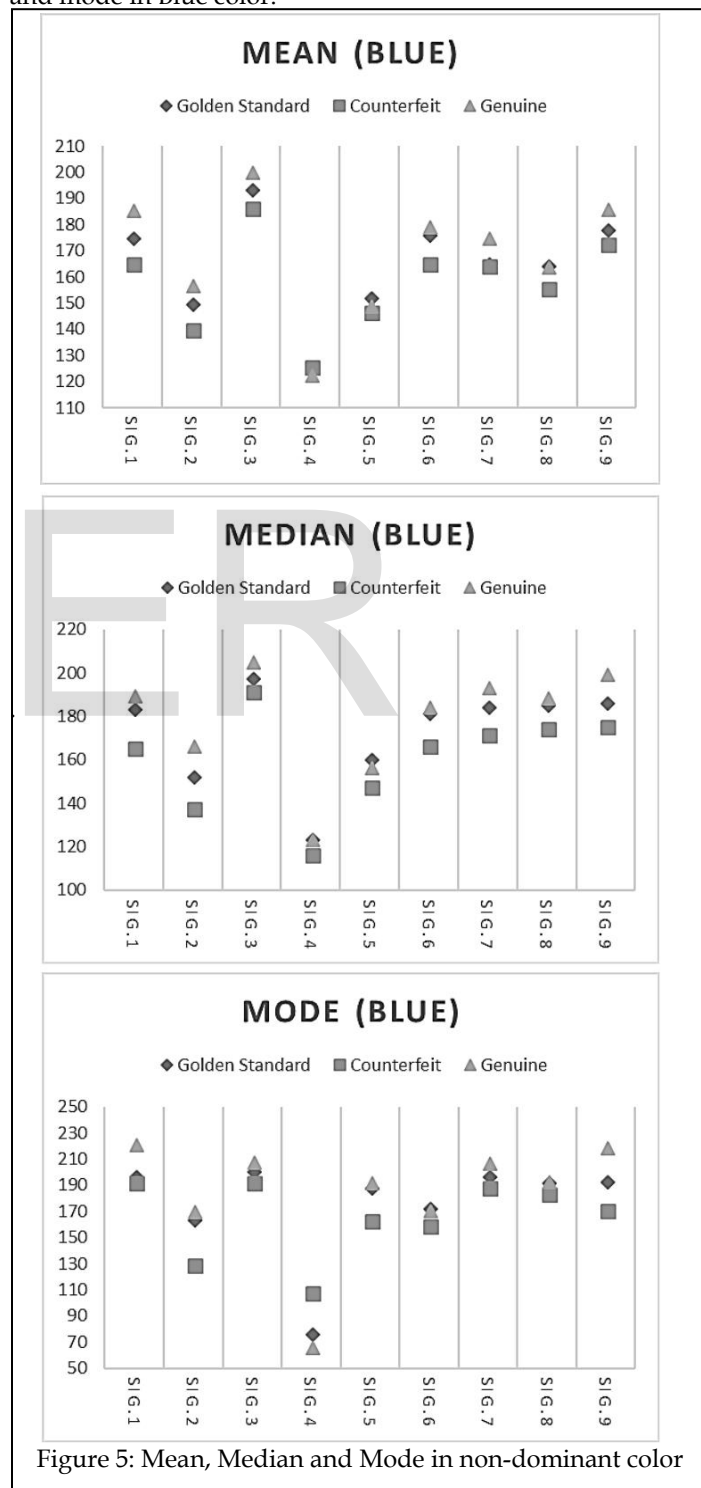

Figure 5: Mean, Median and Mode in non-dominant color

Mismatch in all the color components in terms of mean, median and mode is indicative of Brightness, Contrast, Hue and Saturation adjustment. Mean, median and mode highlight the photometric information of the image.

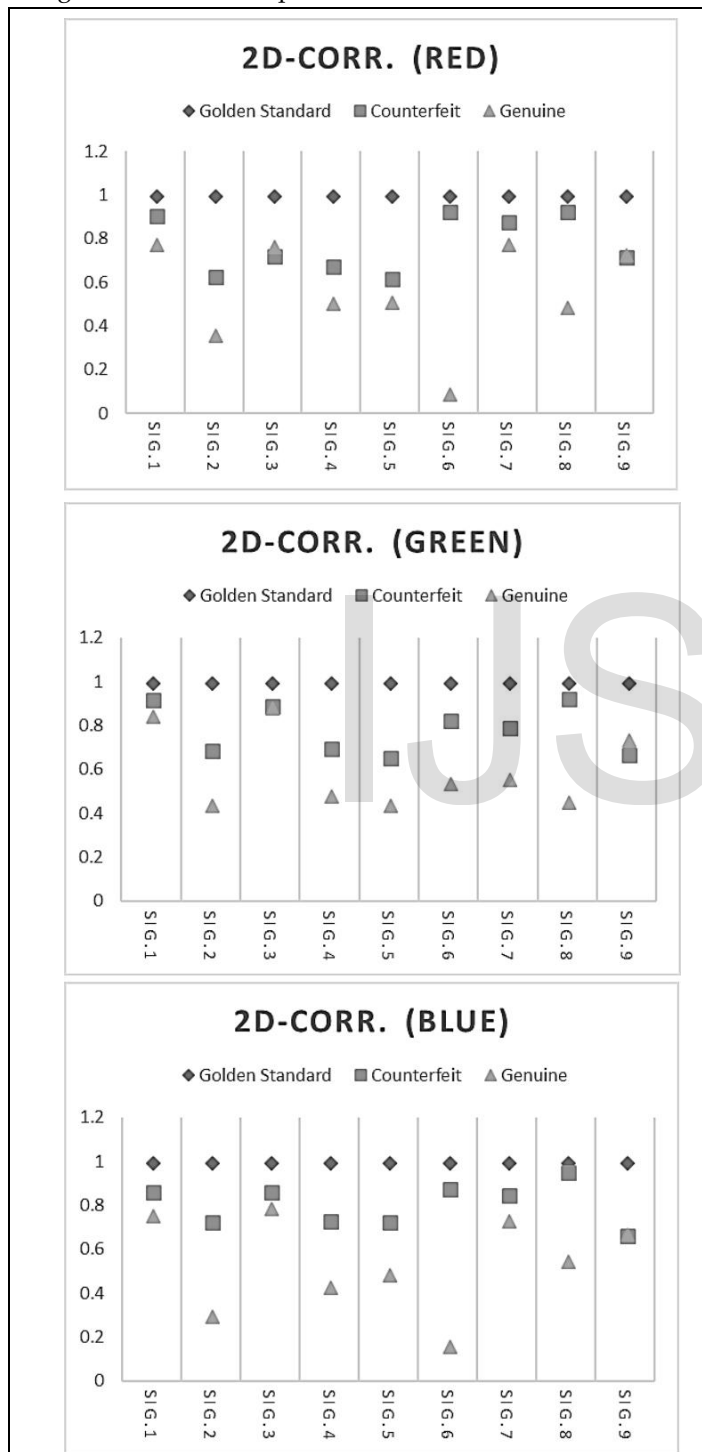Next, we look at the 2D correlation across the signatures in red, green and blue components.

2D- Cross Correlation is bad in all the colors indicative of the fact that Rs 2000 Note design not only in terms of size of features but also their relative placement in the Banknote. Thus this form of analysis has failed due to non-uniformity in print in Indian Currency rather than our detection method. Visually we can compare the signatures in figure 7 which show two genuine banknotes of Indian Currency are geometrically much different.

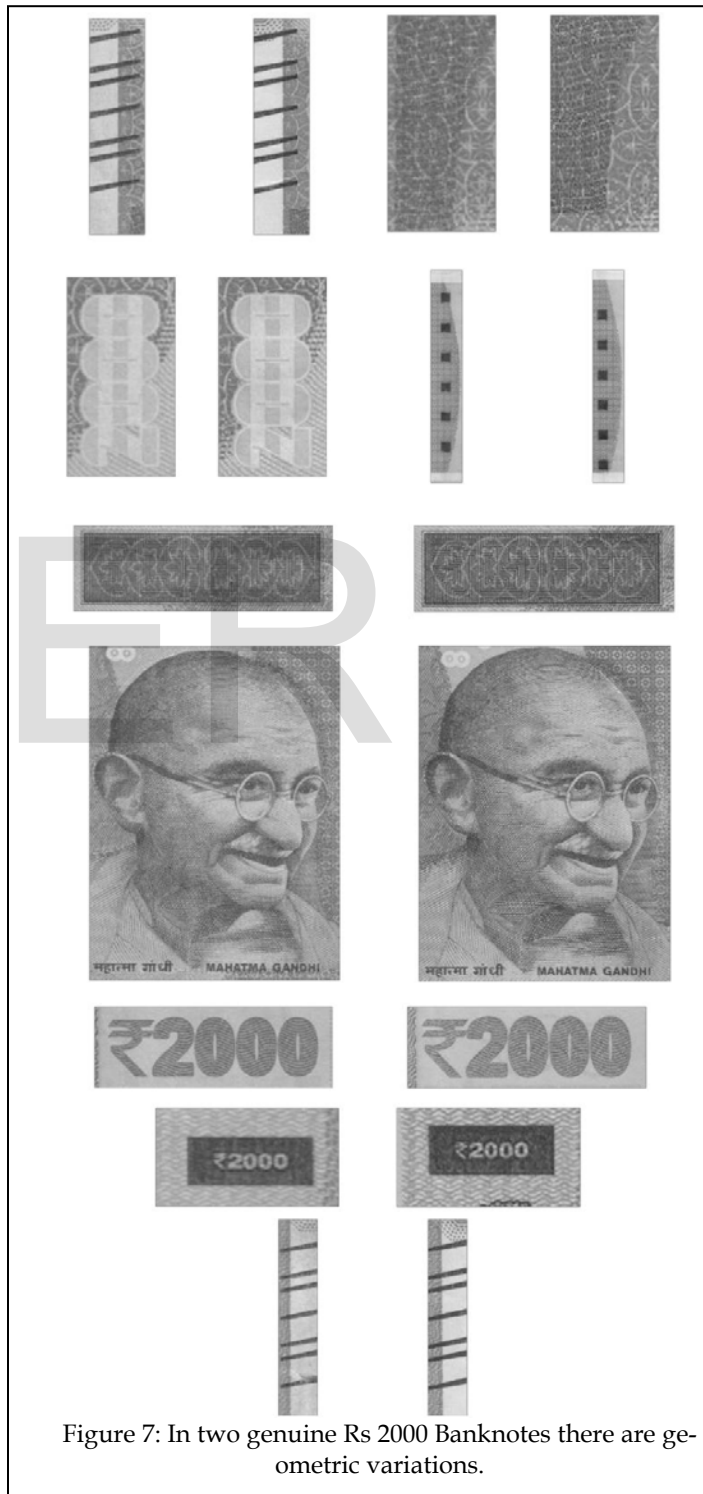Figure 6: 2D-Correlation with Golden Standard across signatures in Red, Green and Blue Component

Figure 7: In two genuine Rs 2000 Banknotes there are geometric variations.

Signature 1 and 9 show that the stretch marks as well as signature 8 done by Intaglio Ink have moved. Texture around signature 8 has significantly changed. Signature 6 shows that the thread was implanted into Banknote from reverse side. Signature 2 has changed significantly between the two genuine banknotes. This is the reason for failure of 2D-Cross Correlation in detecting counterfeit reprint.

In light of this fact, we resorted to pixel distribution in red, green and blue components using Histogram Analysis.
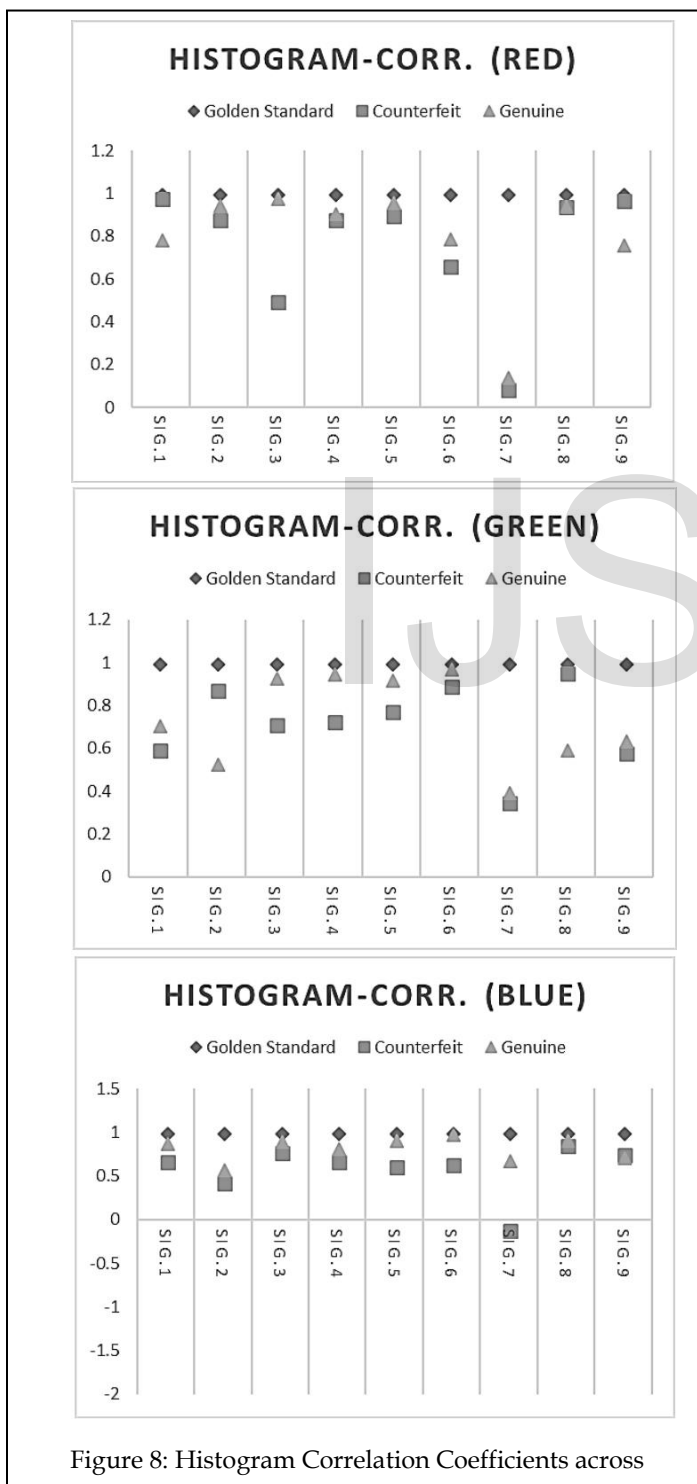

Figure 8: Histogram Correlation Coefficients across

Figure 8 shows that the counterfeit banknote failed on Signature 7 which we had done intentionally. Histogram Correlation is a Geometric-Photometric Hybrid technique which proves to be best for decision making in the light of the fact that Indian Bank has numerous designs of same Rs 2000.

5 CONCLUSION

Statistical analysis of safety signatures built into the design of currency notes provides valuable information about counterfeit notes and genuine notes. Mean, median and mode analysis of signature reveals that printer in open market has different color composition than the equipment used in Indian Currency. This fact can be used to detect counterfeit currency especially when brightness, contrast, hue and saturation adjustments are made in counterfeit banknotes.

2D-cross correlation can provide valuable information in detecting counterfeit currency maintains design uniformity across its bills [6].

Histogram correlation is the best tool with the mix of information from photometric and geometric domain to establish authenticity of Banknotes despite design variations.

6 FUTURE SCOPE

Special frequency analysis on signatures can provide significant information to differentiate counterfeit banknote from genuine banknote. Principal Component Analysis can exactly establish the difference between the two based on Eigen vectors and values. This is left as a scope for the future research.

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