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Forensic Examination of Counterfeit Indian Currency based on Unique Obscure High Security Features in New Indian High Denomination Currency Note



الفحص الجنائي للعملة الهندية المزيفة استنادا إلى ميزات الأمان العالية الفريدة في أوراق الفئات الكبيرة من العملة الهندية الجديدة

Ritika Verma ^{1,*}, Pookalangara N. Ramakrishnan ¹

^{1,*} Central Forensic Science Laboratory, Directorate of Forensic Science Services, Ministry of Home Affairs, Government of India, Ramanthapur, Amberpet post, Hyderabad- 500013, Telangana, India.

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Abstract

Rampant cases related to circulation of fake currency notes have been reported worldwide. With the introduction of new banknotes (announced after demonetization) having advanced and exclusive security features, it is the need of the hour, especially for a forensic Scientist, to have an idea about these new features and the various methods to examine these features.

Results presented in this paper are based on examination and comparison of original and suspected fake 2000 rupee Indian currency banknote utilizing physical examination methods and techniques such as physical, microscopic, digital image processing, etc. During the examination of original 2000 rupee banknote, it was found that some security features of this banknote are unique & exclusive and could not be forged by counterfeiters. Counterfeiter could only imitate most of the visual features of banknotes but some specific security features like OVI print, UV-fluorescent print, micro letters, etc. which are placed on all over the substrate of original banknote, could not be mimicked. However, imitation of the visual features, can at times deceives the public in general.

The present case study presents a methodology which will be very useful and informative in assisting the forensic community in examination of fake currency banknotes and for future studies.

المستخلص

لقد تم الإبلاغ عن العديد من الحالات المتفشية التي تتعلق بتداول الأوراق النقدية المزيفة في جميع أنحاء العالم. ومع إدخال الأوراق النقدية الجديدة (التي أعلنت بعد إبطال الفئات السابقة) ووجود ميزات الأمان المتقدمة والحصرية فيها، وهي تعتبر حاجة في هذا الوقت، وخاصة بالنسبة لعلماء الأدلة الجنائية، للحصول على فكرة عن هذه الميزات الجديدة والطرق المختلفة لفحص هذه الميزات.

تستند النتائج المعروضة في هذه الورقة العلمية على فحص ومقارنة أوراق العملة الأصلية مع أوراق العملة الوهمية المشتبه بها من فئة ٢٠٠٠ روبية من الأوراق النقدية للعملة الهندية، باستخدام أساليب الفحص المادي وتقنيات مثل التقنيات المجهرية والتقنيات الفيزيائية، ومعالجة الصور الرقمية، الخ.

خلال فحص الأوراق النقدية الأصلية فئة ٢٠٠٠ روبية، وجد أن بعض الميزات الأمنية لهذه الورقة النقدية هي فريدة من نوعها وحصرية ولا يمكن تزويرها من قبل المزورين. يمكن أن يقوم المزور بتقليد معظم الميزات البصرية فقط من الأوراق النقدية ولكن بعض ميزات الأمان المحددة مثل الطباعة المسماة (أو في أي) OVI، والطباعة الفلوريسية المظهرة بالأشعة فوق البنفسجية، والأحرف الصغيرة، وما إلى ذلك من العلامات التي توضع على جميع أنحاء المادة الأساسية في الأوراق النقدية الأصلية، لا يمكن محاكاتها، ومع ذلك، فإن تقليد الميزات البصرية، في بعض الأحيان يخدع الجمهور بشكل عام.

وتقدم دراسة الحالية الطرق المنهجية التي ستكون مفيدة جداً وواضحة بالمعلومات لمساعدة دوائر الأدلة الجنائية في فحص الأوراق النقدية المزيفة ولمساعدة الدراسات المقبلة.

Keywords: Forensic Science, Security Features, Counterfeit Currency, Physical Examination, Image Processing.

الكلمات المفتاحية: علوم الأدلة الجنائية، ميزات الأمان، العملة المزيفة، الفحص الفيزيائي، معالجة الصور.



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* Corresponding Author: Ritika Verma

Email: ritikaverma.2@gmail.com

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1. Introduction

Currency, is a most specific word, which refers to money in any form which is in circulation as a medium of exchange, especially in the form of banknotes and coins [1, 2]. The Indian rupee (symbol ₹; code: INR) is the official currency of India and the Reserve Bank of India (RBI) has the sole right to issue currency notes. With the advancement of science, counterfeiting/forgery of higher denomination banknotes has become an inherent challenge in issuing currency. Due to this, various security printing methods have been introduced to curb the counterfeiting of the banknotes in recent years. It has been observed by security agencies of India that the fake banknotes are frequently smuggled into India mostly from the border areas, so as to facilitate various terrorist activities, smuggling of arms and drugs etc. which directly impacts the economic security of the country. This has led to demonetisation of ₹500 and ₹1000 old banknotes, followed by launch of new ₹ 2000 denomination banknotes on 8th November, 2016 by the Indian Government [2,3,5].

RBI has issued ₹ 2000 denomination banknotes in the Mahatma Gandhi (New) Series. The new banknote of highest denomination has various new designs, geometric patterns with the overall colour scheme, both at the obverse and reverse side. The salient features of the banknotes published by RBI [3] are as under:

1. Value = ₹2000
2. Dimension of the banknote is length 166 mm & Width 66 mm.
3. The base colour of the note is Magenta
4. Years of printing November 2016 – Current
5. Bearing signature of Governor, Reserve Bank of India.
6. Theme of the banknote is “Motif of Mangalyan depicting country’s first venture into interplanetary space”.

banknote face wise features are as follows:

Obverse:

7. See through register in denominational numeral 2000 can be seen in transmitted light.
8. Latent image of the denominational numeral 2000 can be seen by placing note at 45° angle.
9. Denominational numeral २००० in Devanagari.
10. Portrait of Mahatma Gandhi at the center
11. Micro letters ‘RBI’ and Rs ‘2000’ on the left side of the banknote.
12. Windowed security thread has inscriptions ‘भारत’ in Devanagari, RBI and numeral 2000 with color shift i.e. Optically Variable due to which Color of the thread changes from green to blue when the note is tilted.
13. Denominational numeral with Rupee Symbol i.e. ₹2000 in optically variable ink (OVI) on bottom right. It changes colour from green to blue when viewed at different angles.
14. Guarantee Clause, Governor’s signature with Promise Clause and RBI emblem towards right of banknote.
15. Mahatma Gandhi portrait and electrotype watermarks.
16. Number panel with numerals growing from small to big on the top left side and bottom right side.
17. Ashoka Pillar emblem on the right.
18. For visually impaired, the banknote is having:
 - Intaglio or raised printing of Mahatma Gandhi portrait, Ashoka Pillar emblem, bleed lines and identity mark.
 - Horizontal rectangle with ₹2000 in raised print on the right
 - Seven angular bleed lines on left and right side in raised print

Reverse:

19. Year of printing of the note on the left.



20. Swachh Bharat logo with slogan.
21. Language panel towards the center.
22. Denomination numeral २००० in Devanagari on right.
23. Motif of Mangalyan.

As soon as this new high denomination currency of India i.e. ₹ 2000 was launched in the market, it has become the prime target of counterfeiters and smugglers to forge the banknote due to the vested interest and to destabilize the economy. As such, many cases of fake currency/banknotes have been received in the forensic laboratories for physical examination and investigation from honourable courts and investigation officer of such cases. Preliminary evaluation of the fake 2000 rupee notes has shown that forgers have managed to imitate most of the features of the new banknotes up to a certain extent due to which a common man may not be able to distinguish between the fake and the original banknotes in a single view. However, they are not able to copy or even imitate few features at all.

The present paper describes the comprehensive case study based on the scientific examination of 2000-rupee original Indian banknote and counterfeit banknotes received in our laboratory. Comparative findings and analysis presented in this paper are based on the exclusive identification features found in new Indian currency and these features are identified using various physical examination methods and techniques like microscope, digital image processing and digital photography etc.

2. Materials and Methods

For this study, some cases of suspected Fake Indian Currency Note (FICN) of 2000 rupee from various cases received in the laboratory for examination in the year 2017-18, were identified for detailed analysis and examination. It was suspected that these seized FICN were brought into India from Bangladesh and was transported to different cities in India. Thus, as a part of the examination, 14 samples

of these suspected banknotes were picked.

To examine these FICN, it is most important to identify security features of new currency launched in the market by RBI and list them. These security features along with some exclusive features of the new 2000 rupee banknote were used to examine all the 14 samples of suspected notes of 2000 denomination received in laboratory. For the present study, various methods and techniques [4-6] like LEICA Comparison Microscope and Digital Image Photography of these banknotes under different light condition (i.e. using direct, through & UV Light) and magnification were used. Moreover, extended deep analysis by image processing, image segmentation and image comparison were also used for extraction and comparison of various characteristics.

Flow chart of examination process of FICN 2000 rupee used is shown in Figure-1. First step to examine any currency note is manual preliminary examination like OVI and intaglio printing observations etc.

Second step is to take photographs of received sample of suspected currency. For the present study, a NIKON D80 digital camera of resolution 300dpi was used to take Digital Photograph of currency (DPC) by exposing these with different light sources like normal white light and Ultraviolet (UV) light. Two types of normal white light source arrangements were used to expose these notes i.e. in direct position and transmitted. Here, the term direct light depicts exposing the exhibit in good light condition, which gives a standard view of exhibits. Examination of photography with transmitted light is the process of shining light through a semi-opaque body, the light source being on the opposite side of the object from the observer, which is generally used in the examination of art works to reveal aspects such as differences in density or thickness or gram-mage variance. Today, most of the banknotes are printed partly using inks containing UV-fluorescent phosphors that glow when exposed to ultraviolet light. Fluorescence is



the physical process where emission of visible light by a substance that has absorbed UV light or electromagnetic radiation is observed. In most cases, the emitted light has a longer wavelength and lower energy than the absorbed radiation. Thus, in the present study, sample specimen and suspected banknotes were also photographed in the presence of UV light to differentiate between them.

Third step is to study microscopic features of banknotes and their comparison for which we used LEICA Comparison microscope. Suspected notes were examined segment wise at different magnifications from 6.3 to 10X. Comparison pictures captured by the equipment were saved in digital form on a PC.

In the fourth step, captured digital images from the second step of examination i.e. DPC were used. These captured digital images were segmented and arranged to extract all the security feature area of the suspected banknote substrate, so that they can be compared with original notes.

3. Results and Discussion

There are some common features of this banknote, as listed by RBI and few exclusive features of this banknote, as identified in the present study which are used to compare the original banknote with the suspected higher denomination of new Indian currency i.e. Rs. 2000/- note. Methods which are used to examine these features of higher denomination of new Indian currency banknote are as follows:

a. Manual Examination

The first method used for the examination of currency notes was manual examination of security features, which can be observed in direct/incident light. Under this examination, some features like quality of banknote substrate, its print, and color, etc. are analyzed. On the basis of comparison and analysis of 14 samples of the suspected banknotes with the specimen, results are tabulated in Table-1.

b. Incident Light Properties (ILP)

Some of the properties of currency when exposed to incident light are already discussed in the above subsection named as Manual Examination Results. Here, incident light DPC is used to capture images for further comparison and examination of security features in detail. One of the feature i.e. geometric patterns present at all four corners of ₹2000 notes is compared in Figure-2. These geometric patterns are printed on both sides of banknotes and have unique features.

These geometric patterns have been cropped from front face of banknotes as shown in Figure-2A. Then, these were arranged number wise as shown in Figure-2B & 2C. For original note (see Figure-2C), these pattern are not similar to each other individually but when connected to each other, they give view of a whole symmetric geometric pattern. Whereas, in case of all the suspected 14 banknotes, this arrangement comes out to be asymmetric pattern, as seen in one of these banknote arrangement shown in Figure-2B.

c. Security Features Visible in Transmitted Light

Photography using transmitted light was used to identify and capture special water marks and see through registration on banknote substrate. Therefore, for examination and analysis of banknotes, DPC was done on the substrate of ₹2000 banknote by shining light through its semi-opaque body.

For ease in observation, these portions of special water mark area and see through registration are marked by dashed yellow square boxes as shown in Figure-3A & Bb for original and suspected ₹2000 banknote respectively. Though counterfeiters have managed to fake most of the features of bank note which are observed using the transmitted light photography, however, features such as font, size and quality of



Table 1- Manual examination of 200 IRBN using various types of light sources.

S.No.	Security features of Specimen 2000 rupee	Observations	Results
1.	OVI detection in <ul style="list-style-type: none"> • Security Thread • ₹2000 on RHS corner 	OVI Not observed	Imitated
2.	Intaglio or raised printing: <ul style="list-style-type: none"> • Mahatma Gandhi portrait, • Ashoka Pillar emblem, • Identity mark: Horizontal rectangle with ₹2000 in raised print on the right • Seven angular bleed lines on left and right side in raised print 	Not observed	Imitated print only
3.	Latent Image	Not clearly visible	Imitated print
4.	Banknote substrate quality; <ul style="list-style-type: none"> • Size of Banknote: Width 166 mm and Height 66 mm • Weight ~ 1.0084 gm • Banknote is printed on a special watermarked paper with substrate cotton and cotton rag. This gives the banknote a unique “feel” and “crackling sound”. • Banknote has paper with increased grammage and calliper thickness. (Thickness Vary from 0.12mm - 0.17 mm) 	<ul style="list-style-type: none"> • Width and Height was found comparatively increased only in ~1 mm • little heavier ~ 1.3 gm or more. • no crackling sound observed. • no variation in grammage and calliper thickness found from ~0.14 mm and on security thread area to ~0.18mm. 	Imitated features observed
5.	Number panel with numerals growing from small to big on the top left side and bottom right side. vary from ~ 3.5mm to 5.5mm	Numbers seems growing but increment in not aligned and vary from 3.5 mm to 5 mm	Imitated print
6.	Colour : The base colour of the original banknote is Magenta	All the suspected banknote were visible magenta with yellow tint in colour.	Imitated colour patterns

marks of original and fake notes can be discriminated clearly. Some of these features include circular ring around “2K” mark, parallel strips near security thread, alignment of see through register, size and font of “2000”, Gandhiji portrait watermark quality, micro letters font and quality on security thread etc.

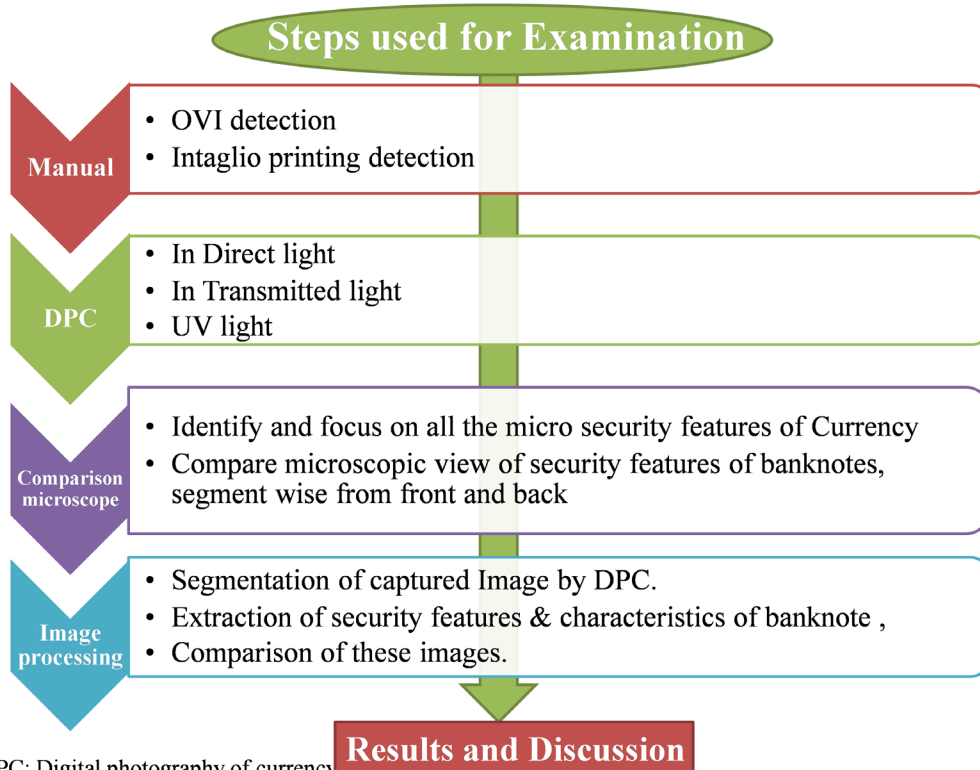
d. UV light Features

Features observed in DPC using UV light for front and back view are shown in Figure-4A & 4B, respectively. Figure-4A shows that in front view of

banknote glowing Gandhiji portrait, curved strips, both number panel and text on security thread can be seen. For back view of banknote (as seen from Figure-4A) glowing mangalyan picture and security thread is seen. Multi coloured optical fibres are also visible embedded on all over the substrate of THE banknote.

But for suspected 14 currency notes, UV-fluorescent print and microfibers embedded in the banknote substrate was not found. From Figure-5 viz. view of





DPC: Digital photography of currency

Figure 1- Methodology used in present research work to examine and identify the FCIN.

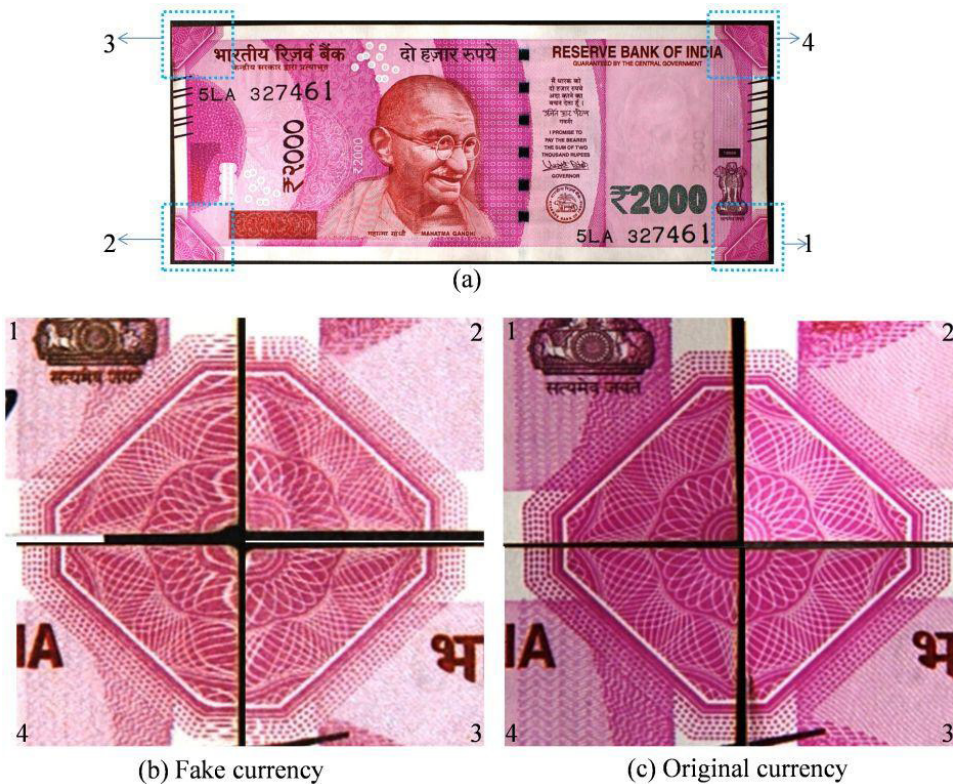


Figure 2- Geometrical patterns found at the corners of banknotes (a) represents 2000 Rs banknote with marked geometrical patterns on front view of note, and number wise arrangement of these as one geometrical pattern is shown in (b) for suspected note and (c) original note.

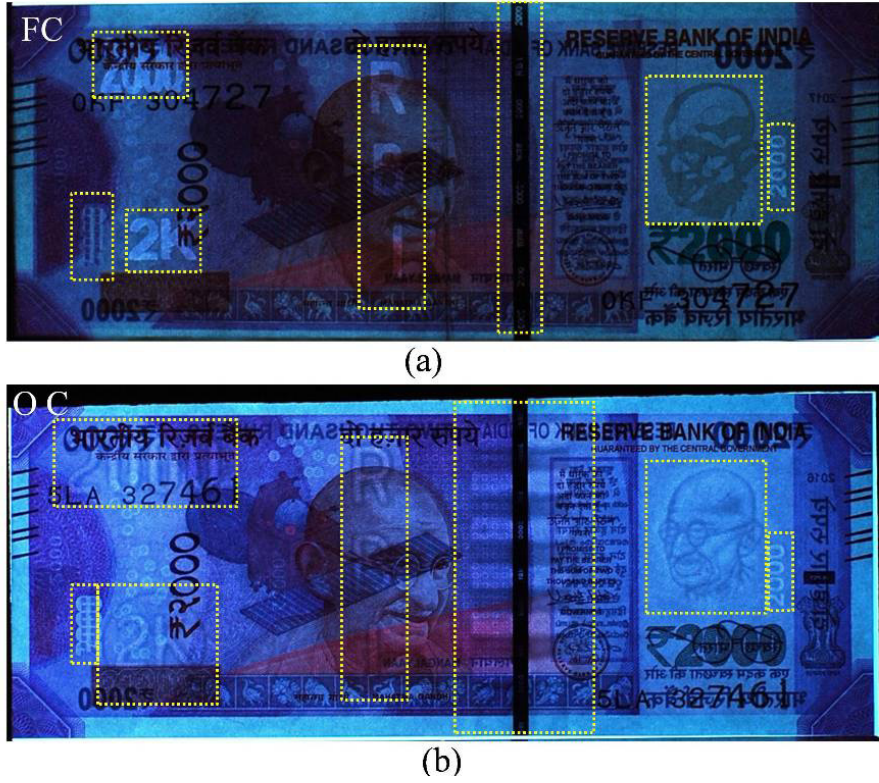


Figure 3- Security feature comparison in through light (a) suspected/Fake currency & (b) Original currency note view in through light with security features like watermarks etc. marked by yellow dotted line boxes.

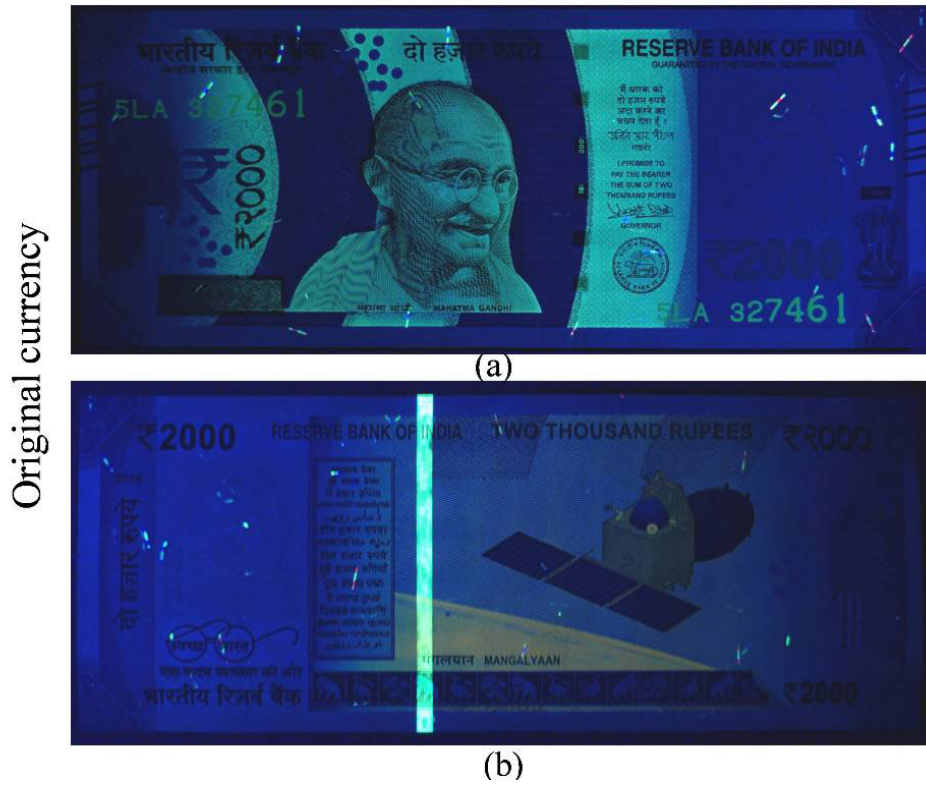


Figure 4- Original 2000 rupee note in (a) front and (b) back view of banknote when exposed to UV light.

Fake currency

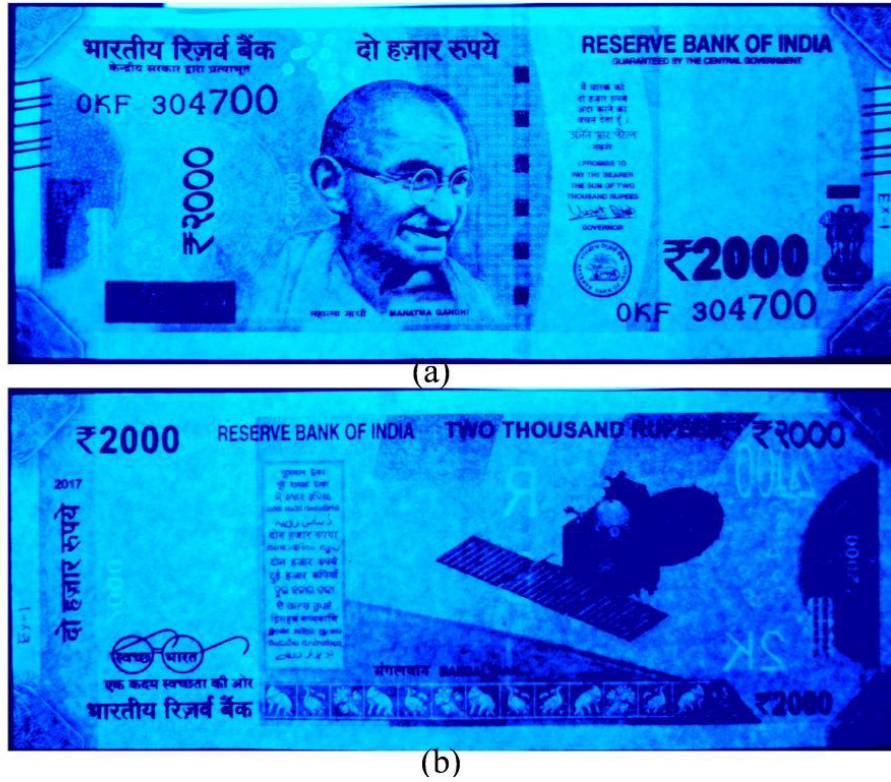


Figure 5- Suspected note (a) front and (b) back view of banknote when exposed to UV light.

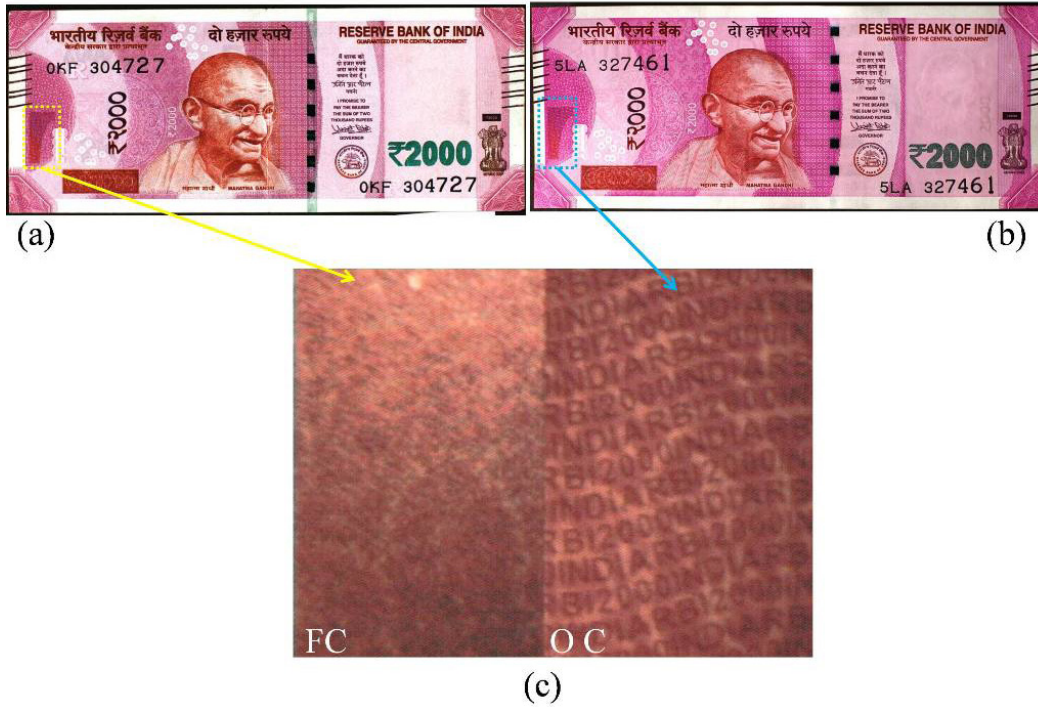


Figure 6- Hidden micro printing comparison between suspected and original note (a) photograph of suspected note with marked micro printing area, (b) photograph of original note with marked micro printing area, (c) LEICA comparison microscope results for both note, at Magnification 12.5x.

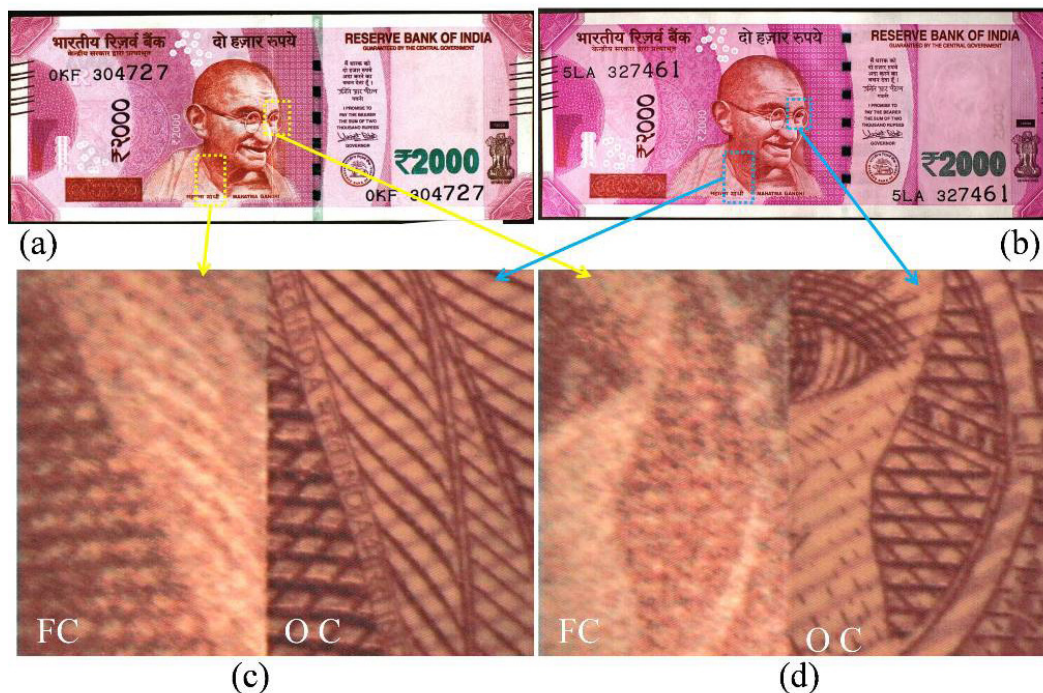


Figure 7- Hidden micro printing comparison between suspected and original note (a) photograph of suspected note with marked micro printing area, (b) photograph of original note with marked micro printing area, (c) LEICA comparison microscope results for both note near collar (d) LEICA comparison microscope results for both note on goggle stick, at Magnification 12.5x.

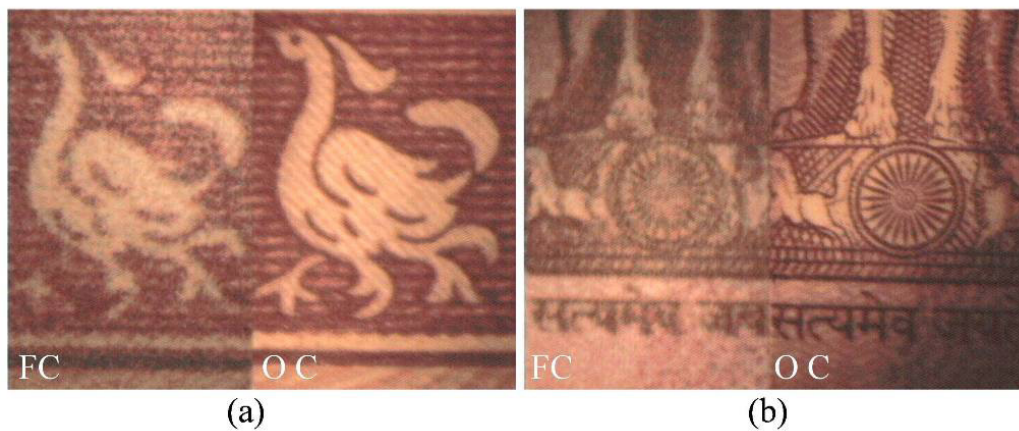


Figure 8- Pictures print pattern quality on banknote (a) LEICA comparison microscope results for peacock pattern found on lower back of note at Magnification 8x (b) LEICA comparison microscope results for Ashok Symbol on front RHS of note, at Magnification 6.3x.

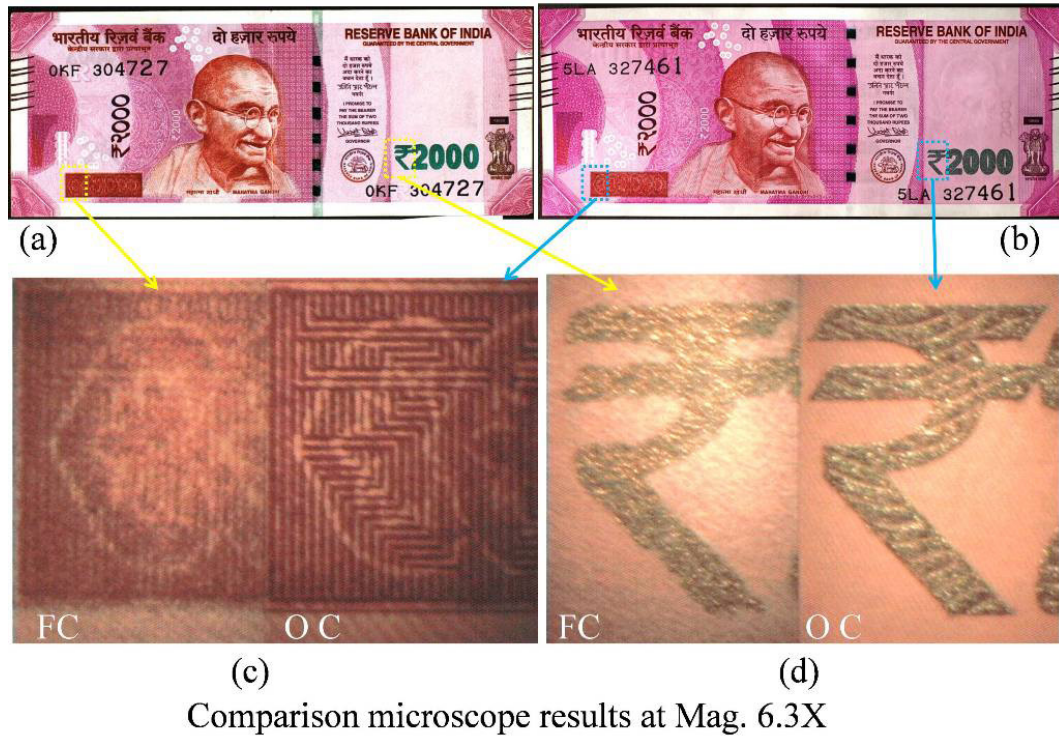


Figure 9- Rupee symbol printing texture comparison between suspected and original note (a) photograph of suspected note with marked area, (b) photograph of original note with marked area, (c) LEICA comparison microscope results for rupee symbol in latent image (d) LEICA comparison microscope results for rupee symbol of OVI printed text at Magnification 6.3x.v

one of the banknote when viewed under UV light, it is seen that the banknote substrate is glowing like normal white paper only.

e. Comparison Microscope Results

According to website of RBI, new ₹2000 banknote has micro letters 'RBI' and number '2000' printed on the left side of the banknote. However when the original currency was examined under microscope, some more hidden features such as micro letter text on the banknote were observed. During examination of original currency using microscope, letters "RBI", "INDIA" & "2000" were seen printed periodically as small patch on left side of banknote. Further, the text "RBI" on goggles near RHS eye and periodic/repeated text "भारत INDIA" on the collar area strip of Gandhi ji portrait were seen. But on examination of all 14 samples of FICN, none of these micro characteristics were found. A close view of

these microscopic characteristics and its comparison with one of the 14 suspected notes are shown in Figure-6 & 7 respectively.

Using comparison microscope, some other features of banknote like printed patterns, quality, sharpness (for peacock print on back and Ashoka chakra area of Ashoka Pillar emblem on front side of note as shown in Figure-8), ₹ symbol print in latent image, parallel lines, and OVI print on RHS of note (Figure-9) were also compared. Faded patterns were visible in suspected 2000 rupee note as compared to high quality print and sharpness of patterns on original banknote, clearly differentiate fake note from original one.

4. Conclusion

Even though there is an increase in the use of digital

transactions in most of the cities of India, but paper currency is still used as a popular mode of payment. As such, circulation of fake notes is always prevalent in an economy. After demonetization of old 500 and 1000 rupee from Indian market, counterfeiters have shifted their focus on forging of newly launched 2000 rupee banknote of India due to its high return value. In the present paper, security features of new 2000 rupee banknote were studied by utilizing different examination method like DPC (in Transmitted and UV light etc.), image processing and use of comparison microscope etc. The security features of this banknote were then used to examine and compare with FICN. Results and discussions based on comparison and examination of all 14 samples of 2000 rupee FICN indicated that counterfeiters have managed to imitate most of the features of new 2000 rupee up to an extent, but they are unable to create features like OVI print, raised print, UV- fluorescent print, and micro letter text etc. Moreover, features of new 2000 rupee which were identified and presented here, can serve as a base for future studies and examination of FICN by forensic examiners. Examination of some features like OVI print and geometric pattern can help a common man to differentiate between high quality FICN and original 2000 rupee banknote.

Abbreviations

FICN	Fake Indian Currency Note
RBI	Reserve Bank of India
OVI	optically variable ink
DPC	Digital Photograph of currency
UV	Ultraviolet
ILP	Incident light properties

Ethics Approval

Not Applicable

Availability of Data and Material

Basic details related to 2000 Rupee is available on RBI Website [3] open for public and other data presented/shown as captured images are done in our Laboratory only.

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None

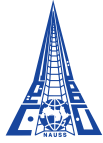
Competing Interests

The authors declare that they have no competing interests.

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A Study for the Determination of Sex by Multidetector Computed Tomography of Sternum using Discriminant Function and Logistic Regression

دراسة لتحديد الجنس عن طريق التصوير المقطعي المحوسب المتعدد الكاشف لعظم القص باستخدام وظيفة التمايز والانحدار اللوجستي

Soumeek Chowdhuri^{1,*}, Priyam Roy¹, Arkadeep Dey¹, Saikat Das¹, Ritwik Ghosh¹

^{1,*} Department of Forensic and State Medicine, Calcutta National Medical College, Kolkata, India.

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Abstract

Post-mortem investigations of skeletal remains as well as radiographs from living individuals provide useful information for the discrimination of sex. Our study aimed to find out a mathematical model to differentiate gender based on greater degree of accuracy than the anthropological measures taken from the sternum obtained from cadaver dissection.

The study was performed on 108 adults who were brought for examination of chest due to various medical reasons. Their age ranged between 18 and 80 years. The cases were selected randomly after considering the inclusion and exclusion criteria. Sternal measurements were taken by studying CT (Computed Tomography) scans.

Of these cases, 73 were males and 35 were females. The discriminant function equation (Df) = 0.071 Manubrial Length + 0.075 Manubrio-Sternal Length + 0.036 Width at S1 + 0.037 Width at S3 - 11.367 (Constant). Overall 80.6% of the sample was correctly classified into their group.

This study revealed that measurements from CT scan of sternum can be used to differentiate between sex of individuals which adds to a great advantage in forensic anthropology.

المستخلص

توفر الفحوص التي تجري بعد الوفاة لبقايا الهيكل العظمي وكذلك التصوير الشعاعي للأفراد الأحياء معلومات مفيدة للتمييز بين الجنسين. وكان الهدف من هذه الدراسة معرفة نموذج رياضي لتمييز الجنس تعتمد بدرجة أكبر الدقة مقارنة بالقياسات الأنثروبولوجية المأخوذة من عظم القص الذي تم الحصول عليه من تشريح جثة.

أجريت الدراسة على 108 من البالغين الذين تم إحضارهم لفحص الصدر بسبب أسباب طبية مختلفة، وتراوح أعمارهم بين 18 و 80 سنة. واختيرت الحالات عشوائياً بعد النظر في معايير الإدراج والاستبعاد. وقد أخذت قياسات من منطقة القص sternal من خلال دراسة التصوير المقطعي (CT) ومسح الصور وإعادة تهيئتها. وكان 73 من هذه الحالات من الذكور و 35 من الإناث.

معادلة دالة التمايز هي: $0.075 + \text{Manubrial Length} + 0.071 = (\text{Df}) \text{ Width at S3} + 0.037 + \text{Width at S1} + 0.036 + \text{Manubrio-Sternal Length} - 11.367 - (\text{Constant})$. عموماً تم تصنيف 80.6% من العينة بشكل صحيح في مجموعتهم.

كشفت هذه الدراسة عن أن القياسات من الأشعة المقطعية لعظم القص يمكن استخدامها للتمييز بين جنس الأفراد ما يضيف إليها ميزة كبيرة في علم الأدلة الجنائية.

Keywords: Forensic Science, Sternum, radiology, sex estimation, CT scan thorax, identificationg.

الكلمات المفتاحية: علوم الأدلة الجنائية، منطقة قص العظم، الأشعة، تقدير الجنس، الأشعة المقطعية لمسح الصدر، تحديد الهوية.



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* Corresponding Author: Soumeek Chowdhuri

Email: smk.kgp@gmail.com

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