Features of Indian paper currency and its validation

ABSTRACT

In this paper the different salient features of the old and new version of Indian paper currency notes have been studied and compared. The list of security features of Indian currencies have been mentioned and discussed. Various kinds of conventional methods that are used to detect authenticity and to recognize a note has been explained. It has been observed that each technique has its own objective and significance. There are many conventional tools that can be used to recognize different features of a note. To classify different techniques, the detection method comprises of two parts i.e., the first line detection method and the second line detection method. Physical dimensions of a paper note along with its thickness have pointed out a new parameter which is the diagonal of a genuine currency note that has been calculated to obtain a proposed standardization and each value differs from different denominations. The classification of different Indian banknotes giving emphasis on its characteristics, both salient and security features, dimensions and detection methods has been mentioned and briefly explained. For validation of the paper currencies two methods have been discussed emphasizing on fuzzy logic framework by taking into consideration a 3-point likert scale and another validation methodology using digital image processing.

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Introduction

The Government of India on 8th November 2016 announced that Indian paper currency notes of value 500 and 1000 would no longer be legal by eliminating the circulation of black money and counterfeit currency notes used for funding illicit activities and introduced new paper currency of value of Indian Rupees 500 and 2000 with changes in the existing pattern and features of other denominations too. Therefore currency and its validation becomes a vast area of research and significant progress has been achieved particularly after demonetization. Different salient features of the old and new version of Reserve Bank of India (RBI) notes have been studied and compared along with the list of security features of Indian currencies that have been mentioned and discussed. Currency validation is the prime goal of any authentication system where some first and second line detection methods focuses upon the vital and significant areas of detection in which some related software implications are required. This helps to ease the problem of checking counterfeit notes to a certain extent. Also currency validation is important for the use of wide range of automated machines like car park ticket machines, public transport ticket machines, launderette washing machines, vending machines etc. The currency validator generally identifies the note according to their size, length, width and thickness using optical and magnetic sensors. A new parameter has been introduced which is known as the diagonal of a genuine currency note by taking into consideration the physical dimensions of a note along with its thickness. For different paper currency notes, the diagonal may also be used as a standard parameter for further

authentication. Moreover, the use of the fuzzy logic based technique for the recognition of counterfeit and worn Indian paper currencies using their characteristics expressed as 3D output surface graphs opens up a new dimension for better validation. Also the digital image processing technique with the help of MATLAB programming can be used as a potential tool to distinguish the contrast between a genuine and fake currency.

Literature Review

In the domain of currency recognition, authentication and detection some work during the mid teens had also been started by various researchers. In the year 2014 (Ali, Gogoi & Mukherjee, 2014) presented a paper that intended to represent an extensive survey of recent technological trends in the recognition and authentication of paper currency notes while identifying the various challenges. They had mentioned the significance of various security features of an Indian banknote along with the classification of various detection techniques of the security features based on first and second line inspection methods. (Mann, Shukla & Gupta, 2015) conducted a comparative study based on different types of security features present on banknotes. They had considered security features of American Dollar, British Pound, Australian Dollar, Euro, Renminbi and Indian Rupees (Rs).

Table 1

Salient features of Indian paper currency notes issued by RBI

Denomination Value	Front side salient features	Reverse side salient features
10 (Old RBI Issue)	See through registered denominational numeral 10 is seen. The front side has a Mahatma Gandhi portrait on right side. When note is tilted windowed security thread reads 'Bharat' in the Devnagari script and 'RBI' alternately.RBI emblem is on the right side. Guarantee clause and Governor's signature at the centre. Ashoka Pillar emblem can be seen on the left side. Number panel with numerals on top right and bottom left sides.	Printed year on the bottom at the centre. Language panel on the left side. Motif of a tiger, an elephant and a rhinoceros, all together as fauna of India.
10 (New RBI Issue)	The registered denominational numeral 10 and its latent image can be noticed. Devnagari script used for the denomination numeral. The direction for Mahatma Gandhi's portrait has been changed. Towards the right hand side RBI emblem, Guarantee clause, Governor's signature can be seen. On the top left and bottom right sides numerals growing in ascending form in number panel. On the right hand side Ashoka pillar emblem can be observed.	On the left side printed year of a currency note is present. Logo of Swacch Bharat Abhiyan along with its slogan can be observed. Towards the centre language panel can be seen. Motif of Sun Temple, Konark, India depicting the country's cultural heritage. On the right side numeral of denomination in Devanagari script.
20 (Old RBI Issue)	See through registered denominational numeral 20 is seen. On the left side vertical rectangle as identification mark can be seen Rest of features are same as 10 (Old RBI Issue).	Features are same as 10 (Old RBI Issue). Only motif of Mount Harriet in Andaman and Nicobar Islands can be seen.
20 (New RBI Issue)	The registered denominational numeral 20 and its latent image can be noticed. Rest of features are same as 10 (New RBI Issue).	Features are same as 10 (New RBI Issue). Only motif of Ellora Caves in Aurangabad, Maharashtra, India can be seen.
50 (Old RBI Issue)	See through registered denominational numeral 50 is seen. On the left side square as identification mark can be seen. Rest of features are same as 10 (Old RBI Issue).	Features are same as 10 (Old RBI Issue). Only motif of Indian Parliament with the flag flying on the flagpole can be seen.
50 (New RBI Issue)	The registered denominational numeral 50 and its latent image can be noticed. Rest of features are same as 10 (New RBI Issue).	Features are same as 10 (New RBI Issue). Only motif of Hampi with Chariot in Nimbapura, Karnataka, India can be seen.
100 (Old RBI Issue)	See through registered denominational numeral 100 is seen. On the left side triangle as identification mark can be seen. Five bleed lines can be seen on the left and right sides. Rest of features are same as 10 (Old RBI Issue).	Features are same as 10 (Old RBI Issue). Only motif of Mount Kanchenjunga, the third highest mountain in the world can be seen.
100 (New RBI Issue)	The registered denominational numeral 100 and its latent image can be noticed. On the right 100 with triangle as identification mark is present. Five bleed lines can be seen on the left and right sides. Rest of features are same as 10 (New RBI Issue).	Features are same as 10 (New RBI Issue). Only motif of Rani ki Vav, Patan district, Gujarat, India can be seen.
500 (New RBI Issue)	The registered denominational numeral 500 and its latent image can be noticed. The transition from green to blue occurs in windowed security thread when the note is tilted. Mahatma Gandhi portrait, Ashoka Pillar emblem and identification mark is slightly raised to help the vision impaired people recognize the currency note. On the right 500 with circle as identification mark is present. Five bleed lines can be seen on the left and right sides. Rest of features are same as 10 (New RBI Issue).	Features are same as 10 (New RBI Issue). Only motif of Red fort with Indian flag can be noticed.

Their study stated that the Omron or anti-copying feature present on Indian currency notes makes it less prone to forgery. In the same year (Kanwal, Jat & Malhotra, 2015) emphasized on various security features on the paper currency of highest denomination in India that was Rs 1000 with Video Spectral Comparator-40 (VSC) which is an integrated composite system comprising of cameras, various light sources including infrared, laser, Ultraviolet etc and filters that assist for the comparison of paper currencies. The VSC uses filters to vary the wavelengths of light falling on the document viewed through a camera and computer monitor. Arshad, Sudagar & Nausheeda, 2017 mentioned some of the methods to detect fake currency like counterfeit detection pen and discussed various security features such as water marking, optically variable ink, security thread, latent image using MATLAB version 13. Again in the year 2017, (Gaikwad, Bhosle & Patil, 2017), (Sahu & Sinha, 2017) and (Pinki, 2017) suggested an approach for the identification of genuine currency notes by emphasizing on various security features on the currency of highest denomination in India that were Rs 2000 and Rs 500. Hangar & Dua, 2017 presented a study to check the usefulness of the security features on Indian bank notes and they analyzed the depth of the problem of counterfeiting. In their paper they suggested the implementation of polymer notes by making the system more secure and reliable. In the year 2017, (Nila et al., 2017) investigated the detection methods by using image processing toolbox in MATLAB and reviewed several other detection methods. In 2020, (Kumar et al, 2020) investigated several security features in the new denomination of Rs 500 currency note. Several types of security features were identified on paper currency notes by varying wavelength with the help of different light sources, magnification ranges and various filters. Recently (Sarkar, 2022) has introduced image processing and fuzzy logic based technique for the recognition of counterfeit and worn Indian currencies using their characteristics expressed as 3D graphs and MATLAB programming.

Salient Features of Indian Currency Notes

Post demonetization, RBI issued Indian currency notes of Rupees 10, 20, 50, 100 and 500 which are entirely different from the previous denomination banknotes and have a number of additional security features. Table 1 shows the salient features of the front and reverse sides of old and new version of Indian banknotes used in the present study.

Security Features of Indian Currency Notes

There are several security features which are built on Indian bank notes that deter counterfeiting. Some of these security features are already incorporated in the substrate during papermaking process and some in the printing process. These features are then further classified into public recognizable features and machine readable features. Figure 1(a) and Figure 1 (b) depict various types of security features present on an old RBI issued Indian currency note of Rupees 100 both at front and rear side respectively.
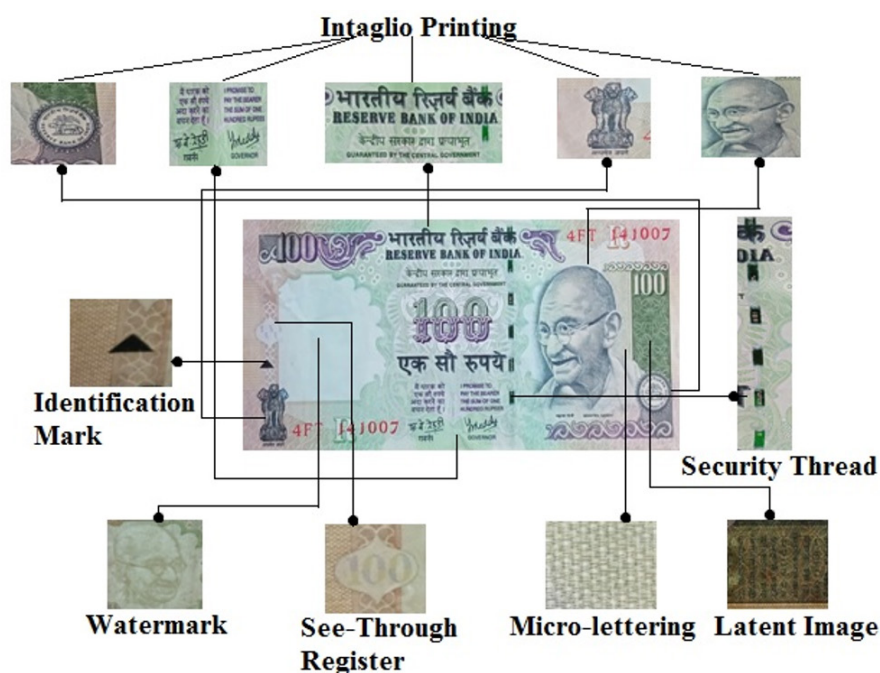
» **Figure 1a:** *Different security features on front side*

Motif of Mount Kanchenjuga

Language Panel

Printed Year
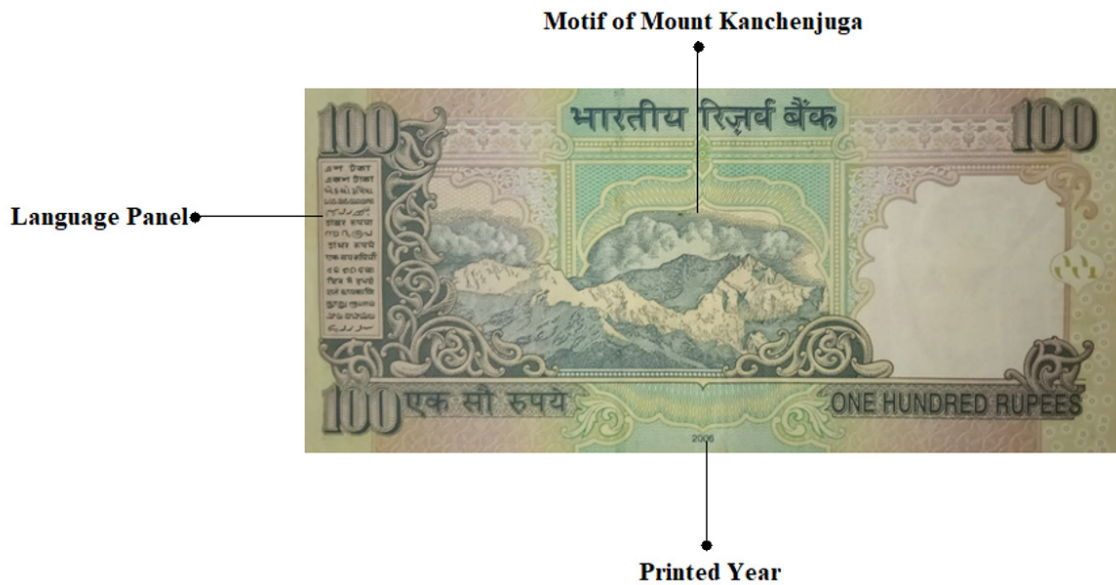
» **Figure 1b:** *Features on back side of the note*

Watermark: The RBI banknotes contain the Mahatma Gandhi watermark having multi directional lines in the watermark window. Due to the varying light intensity the watermark becomes visible when bright light is illuminated on the rear side creating a light and shade effect. Figure 2 shows the enlarged image of watermark present on Rs 100 Indian currency note.

» **Figure 2:** *Watermark*

Ultraviolet fluorescence: The serial numbers or number panels of the currency notes are printed by using fluorescent ink. It becomes bright when illuminated with Ultra Violet Lamp from the reverse side of the currency note.

Intaglio printing: The RBI denominations contain the portrait of Mahatma Gandhi, guarantee and promise clause, RBI governor's signature, Reserve Bank seal, Ashoka Pillar Emblem are printed in raised prints i.e.; in intaglio. The raised prints for identification mark on the denomination of Rs 20, Rs 50, Rs 100 and Rs 500 can be felt by touch except for Rs 10. Following Figure 3 shows different types of raised prints present on Rs 100 currency note.

Micro-lettering: It is a feature that appears between the Mahatma Gandhi Portrait and the vertical band where some texts are printed in less than one point size. In the denomination notes of Rs 20 and above it contains the denomination value and in Rs 10 the word 'RBI' is present in micro letters. Figure 4 shows the enlarged image of micro-lettering present on Rs 100 Indian currency note.

Security thread: The denominations of Rs 10, Rs 20 and Rs 50 notes contain windowed security thread with inscriptions of 'Bharat' in Hindi and 'RBI' simultaneously. On the other hand the RBI denominations of Rs 100 and Rs 500 contain windowed security thread alternative-
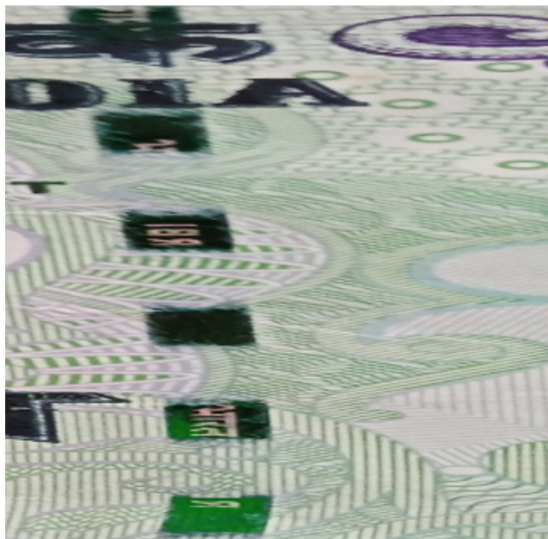

» **Figure 3:** *Different types of raised prints present on Rs 100 currency note*

ly visible on reverse side with inscription 'Bharat' (in Hindi) and 'RBI'. Figure 5 portrays the image of security thread present on Rs 100 Indian currency note.

» **Figure 4:** *Micro-lettering*

» **Figure 5:** *Security Thread*

Optical Security fibers: These types of fibers are the colored viscous fibers that are mixed in cotton pulp during the manufacturing process of the paper. In genuine banknotes, there are three colored optical fibers and those are blue, yellow and green.

Optically variable ink: This security feature has been incorporated in Rs 500 notes with revised color scheme. The numeral 500 is printed with optically variable ink by using a color shifting ink. The color of the numeral remains green when the note is held flat but when held at an angle it changes to blue. Figure 6 displays the image of optically variable ink present on Rs 500 Indian currency note.

Identification mark: For the benefit of the visually impaired people identification marks have been introduced in the RBI currency notes. It is in different geometrical shapes for different denominations. Each currency note has a unique mark for its recognition. This security feature is in distinct shapes for various denominations such as Rs. 20-Vertical Rectangle, Rs.50-Square, Rs.100-Triangle and Rs.500-Circle. Figure 7 illustrates the image of identification mark present on Rs 100 Indian currency note.

» **Figure 7:** *Identification Mark*

Latent image: The RBI notes have a vertical band on the right of Mahatma Gandhi's portrait which shows the denominational value in the form of numeral when it is held horizontally at the eye level. Rs 20, Rs 50, Rs
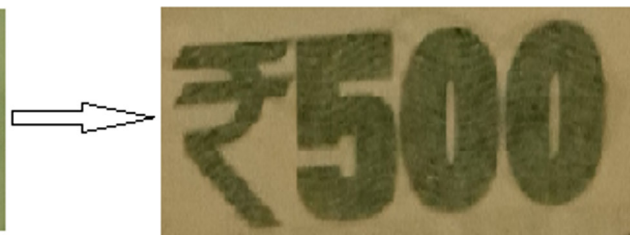
» **Figure 6:** *Transition of green to blue using optically variable ink on Rs 500*

100 and Rs 500 have a vertical band on the right hand side of the portrait of Mahatma Gandhi containing latent image showing the respective denominational value in numeral form. Figure 8 depicts the latent image present on Rs 100 Indian currency note.
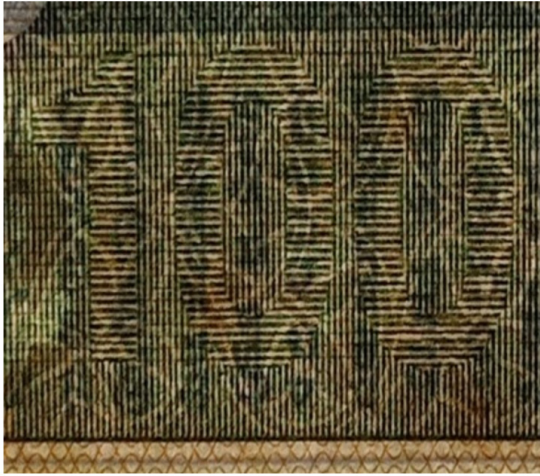
» **Figure 8:** *Latent Image*

See-through Register: This feature is present in a small floral design on the front and reverse side of the currency notes. It has an accurate back to back registration and in present in the middle of the vertical band next to watermark. Figure 9 shows the image of see- through register present on Rs 100 Indian currency note.

» **Figure 9:** *See through Register*

There are some additional features present on an Indian currency note on both front and back sides:
Number Panel: It is a unique, distinct and special font where the spaces between the numbers are evenly distributed. The numbers are thick and bold in color.
Paper quality: Special type of paper is used in order to give longer life to a currency note and make it more difficult to counterfeit.

Gradient coloring: Currency notes are printed with color gradients in such a way that a small change in color cannot figure out the variations with the help of copier, scanner etc.

Holograms: Many currency denominations contain holograms which are the most modernized security features. As a result holograms have been incorporated into banknotes as stripes, patches, security threads, and window features.

Anti-copying feature: In the late twentieth century this feature has been incorporated in currency notes. These are special types of decorations and lines that are incorporated in a banknote with the help of special hardware as well as software that makes it difficult to be copied.

Color changing effect: This is a special kind of effect, in which the color changes when the imprint is viewed from different angles. It is also one of the newly introduced features present in modern banknotes.

Denomination marks: Nowadays to prevent counterfeiting, the denomination marks are repeated in several ways such as in micro texts, backgrounds, etc. The size of the numerical is large and written several times in different locations on a banknote.

Numbers: Some security features are related with the Numbers written on a banknote. The Numbers present on the currency notes have special characteristics as every currency note has its own unique number and they never repeat.

Complicated portraits: Currently most of the banknotes in the world possess portraits. Due to the presence of fine details in a portrait, this feature is difficult to copy.

Standardization of Physical Dimensions of Currency Notes

In the present study, total 50 genuine currency notes have been considered. The grouping of each denomination is done in a way where each old version of RBI currency and new version of RBI currency has been randomly selected because each genuine currency note has an equal chance of being chosen. Five numbers of samples of each denomination for both new and old version has been taken under consideration for the present investigation. Since old version of RBI currency notes are currently not circulated in the market, so only new version of RBI Rs 500 has been considered. Table 2 mentions the grouping of currency notes considered for further analysis.

The currency notes that have been chosen in Table 2 are considered while measuring the thickness of

Table 2

Details of denominations considered for present study

S. No.	Denomination	No. of randomly selected old RBI issue currency notes	No. of randomly selected new RBI issue currency notes	Total No. of notes
1	Rs 10	5	5	10
2	Rs 20	5	5	10
3	Rs 50	5	5	10
4	Rs 100	5	5	10
5	Rs 500	-	10	10

Table 3

Physical dimensions of the denominations used in the present study

S No.	Denomination	Color of the Denomination	Length (L) in mm	Width (W) in mm	Measured Aspect Ratio (W/L)	RBI standard Aspect Ratio (Sawant & More, 2016)	Standard Deviation Values of Measured Aspect Ratio	Thickness in mm	Diagonal in mm
1	Rs 10 (Old RBI Issue)	Orange-violet	137 mm	63 mm	0.46	0.45	0.0054	0.094 mm	150.8 mm
2	Rs 10 (New RBI Issue)	Chocolate brown	123 mm	63 mm	0.51	0.51	0.0045	0.095 mm	138.2 mm
3	Rs 20 (Old RBI Issue)	Pinkish orange	147 mm	63 mm	0.43	0.42	0.0054	0.097 mm	159.9 mm
4	Rs 20 (New RBI Issue)	Green-yellow	129 mm	63 mm	0.49	0.48	0.0044	0.094 mm	143.6 mm
5	Rs 50 (Old RBI Issue)	Yellowish purple	147 mm	73 mm	0.50	0.49	0.0083	0.095 mm	164.1 mm
6	Rs 50 (New RBI Issue)	Fluorescent blue	135 mm	66 mm	0.49	0.48	0.0044	0.092 mm	150.2 mm
7	Rs 100 (Old RBI Issue)	Blue-green	157 mm	73 mm	0.46	0.46	0.0054	0.093 mm	173.1 mm
8	Rs 100 (New RBI Issue)	Lavender	142 mm	66 mm	0.46	0.46	0.0044	0.092 mm	156.6 mm
9	Rs 500 (New RBI Issue)	Stone grey	150 mm	66 mm	0.44	0.43	0.0033	0.095 mm	163.9 mm

the notes using a dial gauge micrometer and also for further analysis. On a currency note there are certain areas where the salient features are present and on those points the thickness is measured and recorded. The mean value of thickness has also been calculated for each denomination (Sarkar, 2022).

For the measurement of diagonal of a genuine currency note a simple method has been adopted where the paper currency may be considered as analogous with the structure of a cuboid and consequently diagonal of the note has been calculated after the determination of length, width and thickness. In Table 3 the diagonals of the old RBI issue and new RBI issue currencies have been calculated and listed beside each denomination accordingly. Therefore it can be postulated that the diagonal considering the thickness of the paper notes can be used as a standard parameter for authentication. It is also observed that standard deviation of measured aspect ratio of new currency notes is always lower than that of the old currency notes.

Detection Techniques of Currency Notes

The detection and recognition methods are broadly classified into two methods- first line inspection methods and second line inspection methods. First-line inspection methods primarily focus upon retailers and vendors who can on spot determine the authenticity of currency notes being exchanged. This includes best guess as well experiences while dealing with banknotes. A second-line inspection method doesn't include verification of currency notes by the naked eye alone, and thus requires a device to perform the authentication function. These devices are more secure and can quickly detect the counterfeit notes than the visual methods (Ali, Gogoi & Mukherjee, 2014).

Counterfeit detection pen: This device is designed to determine whether the note is counterfeit or genuine. The construction of this pen is quite similar to a felt tip

"Flair" pen. It is a plastic tube having a polyester reservoir that is impregnated with a solution of iodine and solvent. Generally the commercial paper is brown in color unless it is bleached and starched. The ink turns black if the note is counterfeit but will remain amber or brown in color when the note is genuine (Deshmane et al., 2019).

UV illumination method: A currency note has a property of absorbing the UV light and a counterfeit note always reflects the UV light. For the detection purpose a UV transmitter and a receiver is used. The note is detected as genuine or fake by depending upon the light received by the receiver. This simple security measure can greatly reduce the threat of banknote forgery (Harjunowibowo, Harati & Budianto, 2012).

Texture based Recognition Technique: This is a very useful feature in currency recognition. Smoothness, coarseness and regularity are the important properties of a texture. The three principal approaches used in image processing are statistical, structural and spectral to describe the texture of a region (Verma, Singh & Agarwal, 2011).

Pattern based Recognition Techniques: Pattern recognition can be defined as the process of recognizing patterns by using machine learning algorithm. Pattern recognition systems are fast enough to recognize familiar patterns quickly and accurately.

Colour based Recognition Techniques: Images delivered by digital cameras that capture the human perception of primary colors in a combination of tri stimulus, namely, red (R), green (G) and blue (B) convert it into electrical signals. The features are extracted, matched and the currency note is detected as genuine or counterfeit (Aziz, 2016).

Currency Localization Techniques: This technique is a mixed approach where currency note in an image is localized first and then different types of threshold based algorithms are applied to determine the denomination of a currency note.

Isocheck/Isogram: This method depends on a specific pattern of lines and/or dots when printed or scanned. Watermarks which are hidden can also be applied in these patterns such that when a particular filter is placed between the viewer and the note, the hidden verification is revealed which in return recognizes and verifies the note as genuine (Kumar & Chauhan, 2020).

Fibre-Based Certificates of Authenticity: This method makes use of unique configurations of fibres that are embedded in the paper based on the characteristics of fibre-optic light transmission. This technique adds up a large cost to the manufacturing process of banknotes but on the other hand it is highly secure and very difficult to illegitimately duplicate (Chen, Mihcak & Kirovski, 2005).

Holograms and Kinegrams: In modern anti-counterfeiting measures these techniques are becoming more and more regularly used. To produce a diffractive optically-variable image devices (DOVIDs) iridescent foils are added to the printed currency notes usually after printing. There are a wide range of resolution possibilities of the vector-based kinegram that are virtually unlimited meaning an array of unique and precise optical effects which are of very high quality are usually impossible to replicate by holography (Lancaster & Mitchell, 2004).

Validation Techniques of Currency Notes

Fuzzy Logic Based Recognition Technique: Recently a new approach for currency verification and authentication has been introduced (Sarkar & Pal, 2022a) using Fuzzy Logic analysis. An integrated system for a quantitative approach has been made for the evaluation of security features present in the Indian paper currency notes. Seven important security features like watermark, security thread, hologram, intaglio printing, latent image, micro-lettering and see-through register have been considered which are already present in the denominations used in this study as well as present in foreign currency notes. These seven security features are applied to the inference system to get the desired output based on a decision making process. The condition of a security feature is classified in terms of its linguistic variables as poor, fair and excellent. This approach depends upon the operation of Fuzzy Logic for the categorization of Indian currency notes as counterfeit, worn and genuine. Three fuzzy variables namely poor, fair and excellent are used to describe the feature variations at the input side and counterfeit, worn and genuine are the variables present at the output. Therefore a currency note's tendency of being worn, genuine, counterfeit can be predicted from the three dimensional output surface curves that consider the membership functions based on the conditions of a security feature being poor, fair or excellent (3-point). A 3-point likert scale can be easily developed by using the fuzzy logic approach. This likert scale now can be generated by considering more number of linguistic variables which may be useful for the recognition purpose. For example the likert scale showing the seven numbers of input variables according to their three numbers of linguistic variables is shown in Figure 10. Depending upon the user this scale may vary if it becomes five or seven or even nine linguistic variables. Similar scale can also be generated for increased number of security features as input variables. The seven number of security features used in this study as well as considering the important security features which are accepted globally, to the

input side with corresponding output gives a cluster of graphs that may predict the tendency of a currency note being counterfeit, worn or genuine relying upon the conditions of security features. Finally the surface viewer concentrates upon the decision making process and gives the outcome as a characteristic three dimensional curve by varying the inputs. These types of curves are obtained by using Fuzzy Logic Toolbox in MATLAB software (Sarkar & Pal, 2022a). This approach may be extended to web based application systems for further validation of every type of currencies across the globe.
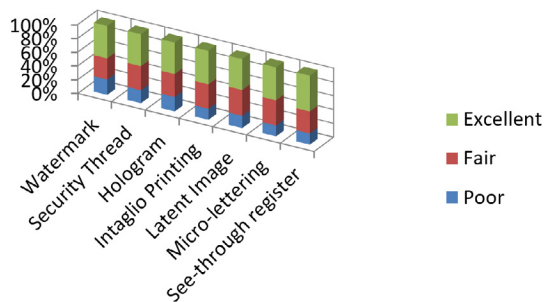

Figure 10: *Likert Scale showing the different input variable according to their linguistic variables*

Digital Image Processing based Currency Recognition: This type of currency recognition takes into account the various kinds of image processing elements for authentication purpose. (Sarkar & Pal, 2022b) suggested a methodology consisting of different image processing components like image acquisition, preprocessing, RGB (Red, Green and Blue) to HSV (Hue Saturation Value) transformation, image enhancement, edge detection using Prewitt, Sobel and Canny Operators, image segmentation, histogram of an image and number of objects detected. The contrast between a genuine and fake currency is obtained with the help of MATLAB coding which is able to sort out the disparities between real and fake currencies. For better validation functionality image processing can be used with machine learning to automate image analysis process. An application based system may be created to validate the characteristics of genuine currency note just by capturing the image.

Conclusion

In this paper a new parameter has been introduced for Indian banknote recognition and it is based on dimensional characteristics of a currency note rather than processing the whole image. An intelligent system on paper currency recognition is inevitable for modern banking service and is to meet the real life needs in this age of technology. Paper currency recognition system has wide range of application in many areas such as automated teller machines (ATMs), auto seller machines, money exchange agencies etc. The dimensional fea-

tures play a very important role for automated currency recognition intelligent systems to carry out successful financial transactions. Apart from the aspect ratio, the average thickness and diagonal of the paper currency note may be used as a standard parameter to authenticate the notes more accurately for the automated teller machines. It can be concluded that a genuine currency should always have particular values of the diagonals for different types of paper currencies.

Security features and detection methods have been discussed which may be helpful to the user as a guide to detect forged banknotes. An effort has been made in comparing the security features as well as the salient features of the old and new versions of RBI currency notes. Currency recognition and detection techniques have also been explained by classifying it in two inspection methods. The validation techniques by fuzzy logic inference system and digital image processing may be useful for recognizing genuine currency notes worldwide.

Funding

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