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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 Devnagri 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.

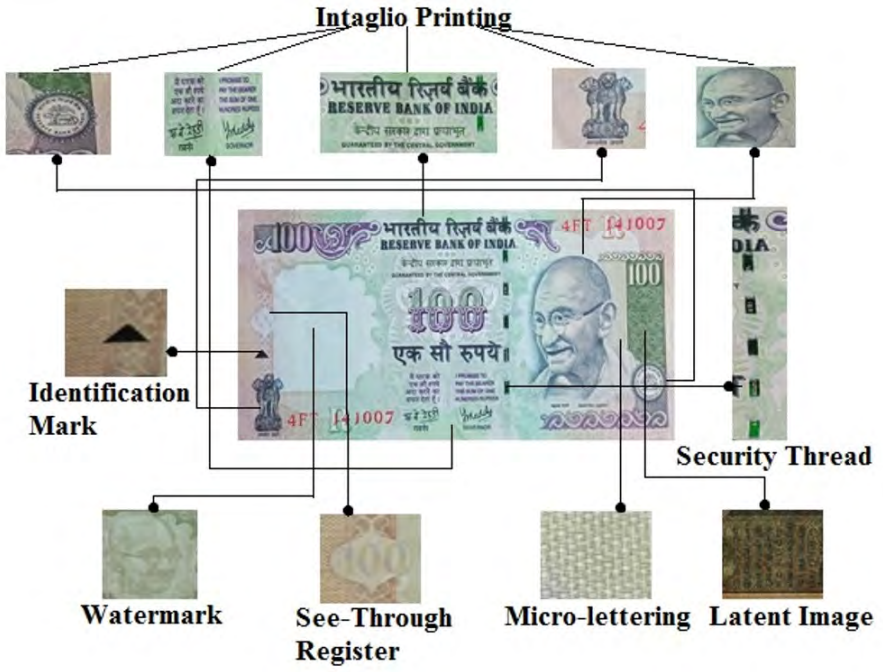
Their study stated that the Omron or anti-copying feature present on Indian currency notes makes it less prone to forgery. In the same year (Kanwal, Jat & Malhotra, 2015) emphasized on various security features on the paper currency of highest denomination in India that was Rs 1000 with Video Spectral 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*

» **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.

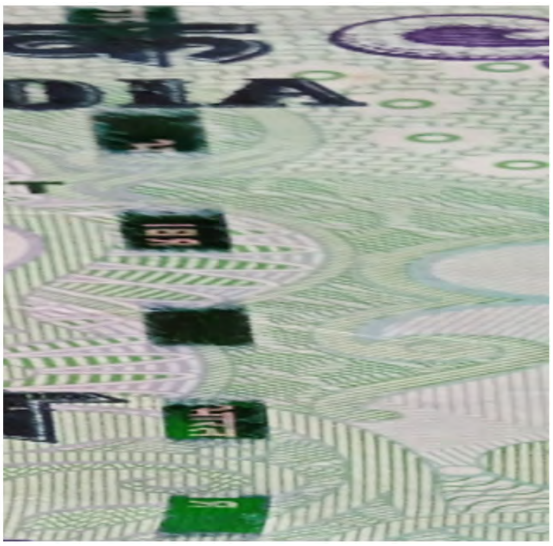
Micro-lettering: It is a feature that appears between the Mahatma Gandhi Portrait and the vertical band where some texts are printed in less than one point size. In the denomination notes of Rs 20 and above it contains the denomination value and in Rs 10 the word 'RBI' is present in micro letters. Figure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

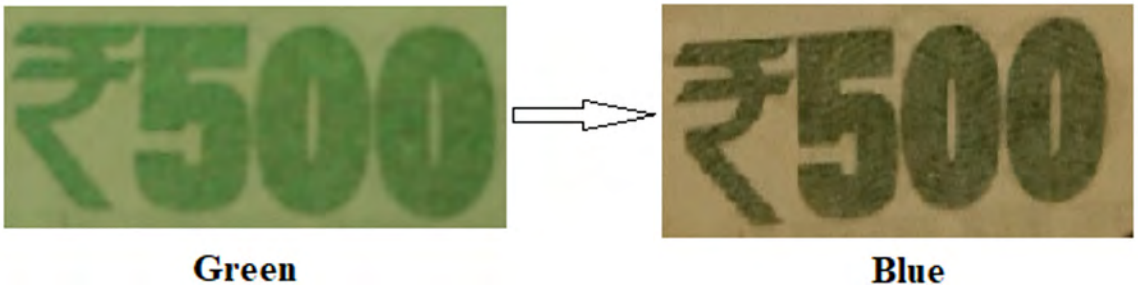
Optical Security fibers: These types of fibers are the colored viscous fibers that are mixed in cotton pulp during the manufacturing process of the paper. In genuine banknotes, there are three colored optical fibers and those are blue, yellow and green.

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.

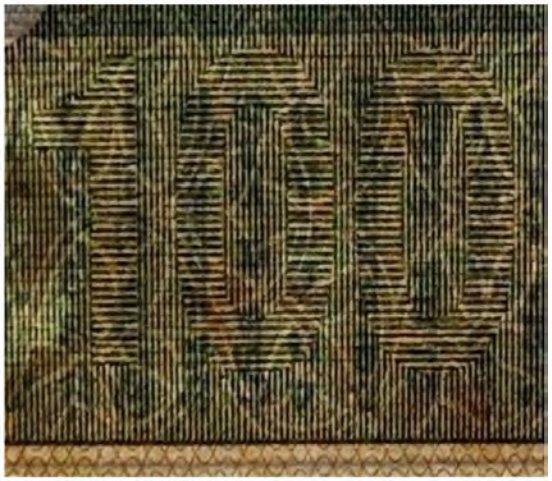
» **Figure 7:** *Identification Mark*

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.

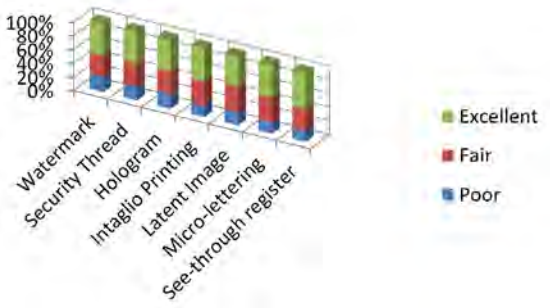


Figure 10: *Likert Scale showing the different input variable according to their linguistic variables*

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 features 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.

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Showthrough and Strikethrough print defect detection using histogram equalization based computer vision method

ABSTRACT

This paper presents a comparatively simple approach for showthrough and strikethrough print defect detection using computer vision method. Showthrough and strikethrough are common printing problem and are typically functions of a paper's opacity. Under normal lighting condition the visibility of printing on the reverse side of printed paper is termed as showthrough whereas the penetration of ink to the other side is termed as strikethrough. Moreover the intensity of showthrough pixel is extremely low thus it is difficult to identify the showthrough pixel from the printed area. On the other hand strikethrough is the result of penetration of ink through paper and depends on the absorbent nature of paper. Comparatively the intensity of the strikethrough pixel is higher than that of the showthrough but due to similar intensity of the ink of the printed pixel and strikethrough pixel, both overlapped with each other in the foreground of the image. These print defects can degrade the image quality as well as print production. In this study, the detection of these two print defects achieved using histogram equalization technique, to enhance the contrast between foreground and back ground pixels. A global thresholding algorithm was applied on a histogram equalized image to segment the printed area from the background of the image. Pixels in the background which are considered as showthrough and strike through pixels are identified by image subtraction. The pictorial representations of the results show the remarkable potential of the proposed technique which can be possible alternative of present subjective measures of showthrough and strikethrough.

KEY WORDS
Showthrough, strikethrough, print defect, histogram equalization, global thresholding, computer vision

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Introduction

Showthrough is a common print defect that is generally found in offset lithography. Paper opacity is responsible for this type of phenomenon while ink absorption and penetration through the paper results in the visibility of printing on the reverse side of a sheet of paper under normal lighting conditions termed as showthrough (Leach & Pierce, 1988). This printing problem occurs in thinner papers with less pulp to create opacity. In both side coated paper there is a polished clay surface on both the sides (Smyth, 2009). Less fiber makes the paper more transparent. The main reason behind the showthrough problem is the combination of ink and paper. Tackiness of ink and excessive acidity of dampening are reasons for many type of print problems (Leach & Pierce, 1988). Strikethrough is similar to the showthrough print problem where the main reason is the penetration of ink through the paper or the substrate. Generally, in porous or uncoated paper this type of problem arises because of the excessive absorbent nature of paper which allows the ink vehicle to penetrate. Moreover,

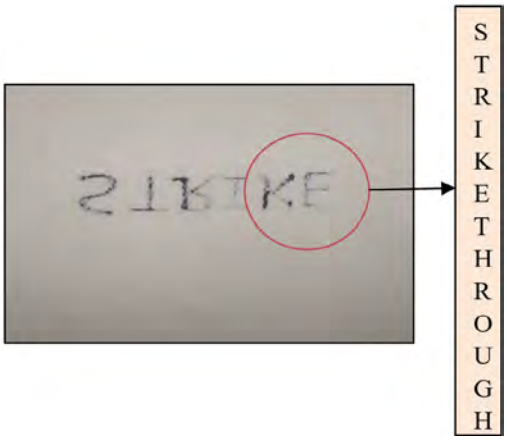
it can also occur when the refractive index of the ink vehicle is close to that of cellulose, making the printed area more transparent. The only remedy to avoid strike-through is to use less absorbent substrate or porous paper, usage of quick set ink and maintain the printing pressure. The ink setting speed is very important criterion to avoid strikethrough as well as showthrough. Moreover, excessive printing impression pressure causes bleeding of the printed object through the paper (Smyth, 2009).

The choice of resin and oil determines the wetting characteristics of ink vehicle. In newspaper printing an asphaltum complex solution in mineral oil with the correct addition (2 or 3%) is used which helps to avoid excessive strikethrough in printing (Smyth, 2009). Filler increases paper opacity, brightness, whiteness and smoothness and reduces ink strikethrough and showthrough by controlling ink absorption (Eldred, 2001). The most common fillers used for this purpose are calcium carbonate, titanium dioxide etc.Paper sizing is one of the most common methods to control the penetration of ink through the paper. Rosin is common sizing agent (Eldred, 2001) that provides significant resistance to wetting paper by ink.

Here in Figure 1 and Figure 2 showthrough and strike-through defected printed sample image is shown respectively. These samples are collected using different offset presses.

» **Figure 1:** *Sample image of Showthrough*

Previously studies in the domain of showthrough printing defect identification are: simplified linearized mathematical model with an adaptive linear filter used to detect the showthrough in the scanned document (Sharma, 2001). Self-Organizing Map (SOM) and Independent Component Analysis (ICA) were implemented to separate the showthrough print defect from a scanned document: (Zhang, Lu & Yahagi, 2007). In another study Non-negative Matrix Factorization methods were applied to remove the showthrough print problem (Merrikh-Bayat, Babaie-Zadeh & Jutten, 2011). Two layer bi-directional neural networks have been proposed to create a cancellation model for showthrough in printing or scanned handwritten samples (Oda & Miyajima, 2014).



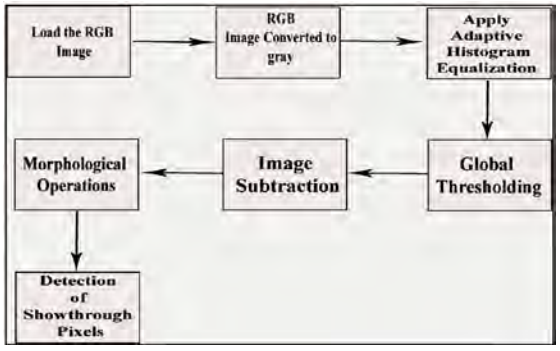
» **Figure 2:** *Sample image of Strikethrough*

The aim of this presented approach of showthrough and strikethrough defect detection is to make much easier procedure in terms of computational load. However, in terms of print quality assessment it is necessary to identify this type of defects using a less expensive procedure. The main purpose of the proposed method is to make the identification procedure of showthrough and strikethrough print defect to be less manual and comparatively less time consuming with an automated detection process.

Presented method

The steps of proposed approach for detecting showthrough and strikethrough print defects are shown in the flow chart in Figure 3. First, defective print samples were collected from various commercial offset presses. Next thickness and porosity of those collected substrate were measured. Thickness of the substrate was measured using micrometer (S.C.Dey & co.). Porosity of the samples was measured by Gurley Densometer. Paste ink and liquid ink were used for showthrough and strikethrough samples respectively.

Digital form of those samples was obtained using an imaging device. Mobile camera with 12 megapixel resolutions in D65 illumination used for the digitalization of all samples. Then the captured original RGB image was converted into a gray scale image. As the gray color space intensity value of pixel ranges from 0(black) to 1(white) and any fractional values in between, it is much easier to perform any image processing operations as it simplifies the algorithm and reduces the computational load. Moreover, the RGB color space is device dependent; as a result pixel information varies from manufacture to manufacture or device to device. Therefore, the gray color space was chosen for further operations. Next, the converted gray image contrast was enhanced by applying histogram equalization method (Mustafa & Abdul Kader, 2018; Kong, 2013; Patel, Yogendra & Sharma, 2013).



» **Figure 3:** *Flowchart of presented method*

In this study contrast enhancement adaptive histogram equalization was used to enhance the contrast of foreground and background images while maintaining the subsequent number of details of the entire image. This step was needed for the segmentation on and detection of showthrough pixels in background as it has low intensity values. To segment the foreground image from showthrough pixel global thresholding algorithm was applied in next step. Selecting a reasonable threshold value was the most difficult task in this step. In global thresholding (Lee, Yoon Chung & Park, 1990) method threshold value was selected by maximizing the class variance. Pixels with a gray level greater than the global optimal threshold value were considered as foreground pixels. However, in the case of showthrough pixel detection, thresholding is not sufficient to detect or segregate the pixels from foreground. Therefore, subtraction algorithm was applied where thresholded image and histogram equalized image were subtracted to obtain the background image that contains showthrough pixels. Morphological operations such as erosion and dilation were performed on the subtracted image to detect the showthrough pixels in the background of the image. The same steps were followed for strikethrough as well. As these two print defects are similar in terms of their causes, the proposed method was applied same manner for strikethrough and showthrough. The intensity of strikethrough pixels are higher than showthrough pixels and due to penetration of ink, strikethrough pixel overlapped with print pixel or other occurring defects such as scumming pixels or tinting pixels. Therefore it becomes difficult to identify and segregate strikethrough pixels from print pixel in the image.

Results and discussion for Showthrough

The presented method was tested with numerous samples collected from offset presses and a mobile camera was used to capture the digital form of these samples. The pictorial results for the four samples are shown in Figure 4, Figure 5, Figure 6 and Figure 7.

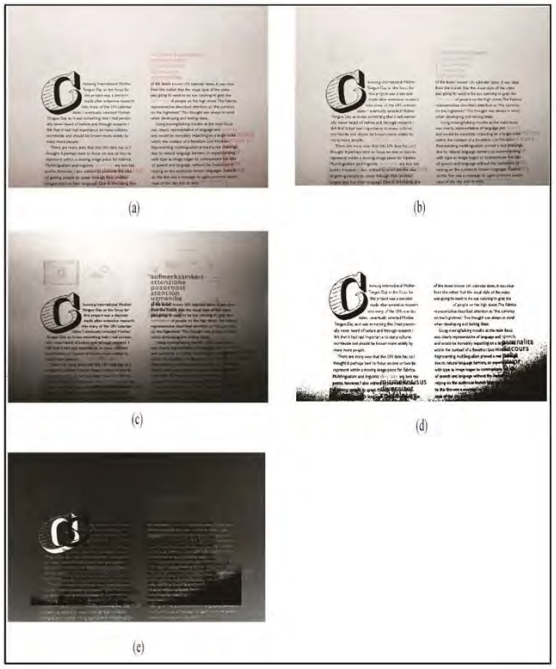
» **Figure 4:** *(a) Original image (b) RGB to Gray Converted image (c) Histogram Equalized Image (d) Foreground Image (e) Detected Showthrough Pixels.*

In Figure 4a original digital image of sample is shown. In this image showthrough is clearly visible in the background and is overlapped with the foreground text which degrades the quality of printed document. Moreover it becomes difficult to identify and segregate the showthrough pixels from foreground text because the showthrough pixel has low intensity. Figure 4b shows the converted gray image of the original RGB image. Figure 4c shows the histogram equalized image of the converted gray scale image. It is shown that after histogram equalization, the showthrough pixels are clearly visible which helps in further operations to detect the pixels in background. After applying the global thresholding In Figure 4d the segmentation of foreground image is shown where it can be seen that only the text to be printed coming as absolute black. Figure 4e shows the showthrough pixels in background image appears in white which ideally should not be present in a good copy.

In Figure 5a it is shown in the original image that the foreground image has some scum pixels which are very difficult to segregate from show through pixels. Therefore as per the proposed method, image is first converted into gray scale is shown Figure 5b Histogram equalized image is shown in Figure 5c. In Figure 5d and Figure 5e the foreground and background image containing showthrough pixels are shown respectively. It is difficult to segregate scum pixels from showthrough pixels in background of the image. The appearance of scum pixels can be considered as a limitation for these images. The limitation can be overcome with the help of image processing tool and post processing operation.

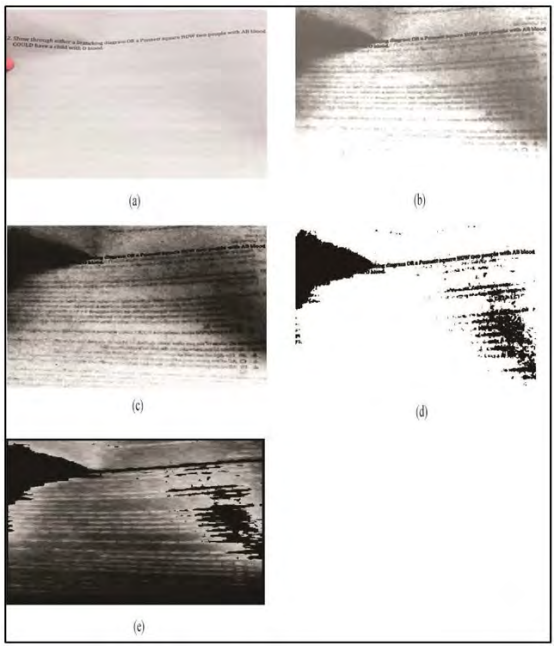
» **Figure 5:** *(a) Original image (b) RGB to Gray Converted image (c) Histogram Equalized Image (d) Foreground Image (e) Detected Showthrough Pixels*

Images of another sample are shown in Figure 6. The main difficulties for this sample arise because of the lighting condition and the presence of other print defects.



» **Figure 6:** *(a) Original image (b) RGB to Gray Converted image (c) Histogram Equalized Image (d) Foreground Image (e) Detected Showthrough Pixels*

The final output image in Figure 6e shows the detected showthrough pixels in white. However, the appearance of scum pixel cannot be ignored and can possibly remove by post processing operations. In case of sample shown in Figure 7 the original image degraded with shadow and showed showthrough pixels. Moreover the intensity of showthrough pixels is extremely low which makes the detection procedure more challenging. Therefore, it is necessary to increase the contrast to detect the pixels in background. After histogram equalization of the gray scale image the contrast is increased and the background pixels are clearly visible in Figure 7c. In Figure 7e the white pixels in background are detected as showthrough pixels and the appearance of shadow can be removed by post image processing operations.



» **Figure 7:** *(a) Original image (b) RGB to Gray Converted image (c) Histogram Equalized Image (d) Foreground Image (e) Detected Showthrough Pixels*

In Table-1 the values for porosity and thickness of the showthrough samples are given.

Table 1

Porosity and thickness of Showthrough substrates

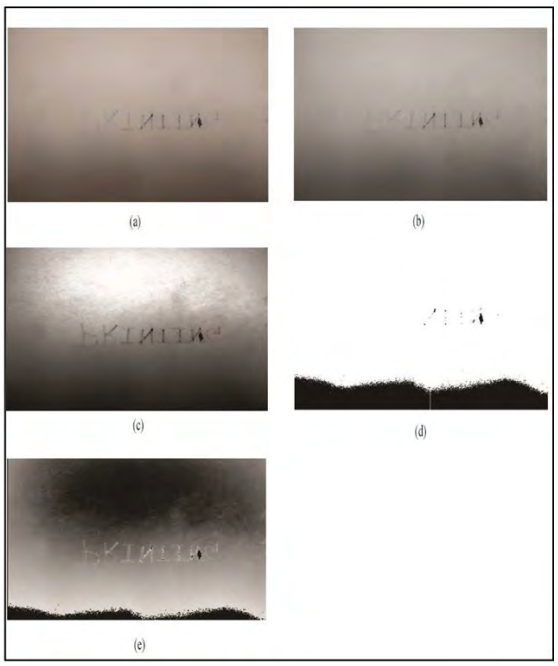
Sample	Thickness (mm)	Porosity (sec)
Sample1 (Figure 4)	0.058	52
Sample 2 (Figure 5)	0.088	40
Sample 3 (Figure 6)	0.055	47
Sample 4 (Figure 7)	0.084	46

According to the measurement sample 2 has the maximum porosity whereas sample 1 has the lowest porosity. The order of porosity (high to low) can be arranged as- Sample 2> Sample 4>Sample 3> Sample 1. Showthrough print defect in Sample 2 is more than other samples as the porosity is high. Sample 1 is less porous and the identification of showthrough

pixels in sample 1 is little bit difficult as it is having lower intensity value. According to the intensity of the showthrough pixel it is clearly visible that Sample 2> Sample 3> Sample 1> Sample 4. It is also observed that though the porosity is less in case of Sample 3, but as the thickness of substrate is lowest, showthrough is more as compared to Sample 1 and Sample 4.

Results and discussion for Strikethrough

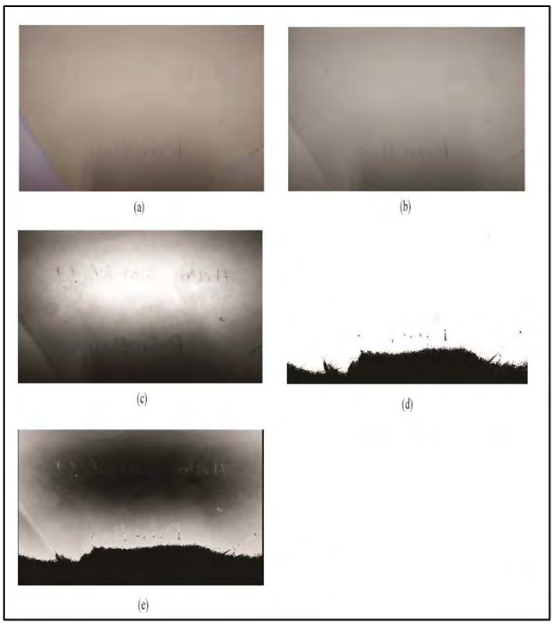
The same proposed method of showthrough detection is followed for strikethrough print defect detection as well. The pictorial representation of the results also proves its strength. In case of strikethrough print defect, the presented method is also tested with no. of samples. Figure 8, Figure 9, Figure 10 and Figure 11 are some of the results of strikethrough detection.



» **Figure 8:** *(a) Original image (b) RGB to Gray Converted image (c) Histogram Equalized Image (d) Foreground Image (e) Detected Strikethrough Pixels*

In Figure 8 (a) the original digital image of strikethrough sample is shown and it is captured using mobile camera only. Here the ink penetrated through the paper fibre and became visible in the foreground of image. However the intensity of the strike through pixels are more compare to showthrough pixels which facilitates the detection procedure. However the presence of other unwanted appearance cannot be ignored and can be removed by further post processing. In this sample presence of shadow made the detection of strikethrough pixels difficult. In Figure 8 (d) in foreground image, the portion of ink that bleeds through the paper is detected. Finally in Figure 8(e) the strikethrough pixels in background are shown in white.

The next sample in Figure 9, because of illumination it is very difficult to identify strike through pixels. Here histogram equalization is required to increase the contrast of background strikethrough pixels for proper detection. The histogram equalized image is shown in Figure 9 (c). Here also the shadow part degrade the image and can be ignored by further image processing operations. Fig. 9 (d) shows the foreground image is shown and Figure 9 (e) shows the strikethrough pixels detected in background.



» **Figure 9:** *(a) Original image (b) RGB to Gray Converted image (c) Histogram Equalized Image (d) Foreground Image (e) Detected Strikethrough Pixels*

The sample in Figure 10 shows that the strikethrough pixels are clearly visible and the presence of unwanted summing pixels makes the segregation of strikethrough pixels difficult. The foreground image in Figure 10 (a) shows the penetrated strike through pixels from reverse side of the paper and the scumming pixels.

To segregate the strike through pixels from scum pixel and print pixel, a proper choice of threshold value is very much important, otherwise scum pixels or print pixels can also be identified as strikethrough pixels, as the intensity value of scum and print pixel is nearly similar to strikethrough pixels. The threshold value was selected by maximizing the class variance of the pixel of the entire image. Pixels with a gray level greater than the global optimal threshold value were considered as foreground pixels. The final result in Figure 10 (e) shows the detected strikethrough pixels in background only and depicts the strength of segmentation of scum pixels and print pixels from the strikethrough pixels.

» **Figure 10:** *(a) Original image (b) RGB to Gray Converted image (c) Histogram Equalized Image (d) Foreground Image (e) Detected Strikethrough Pixels*

In the fourth sample in Figure 11 (a), ink mostly penetrates from the reverse side and is detected in the foreground image in Figure 11 (d) after thresholding operation. Ideally the foreground image should be blanked but here the ink bleeded through the fibre and appears in foreground. The strikethrough pixels detected in white are shown in Figure 11 (e).

» **Figure 11:** *(a) Original image (b) RGB to Gray Converted image (c) Histogram Equalized Image (d) Foreground Image (e) Detected Strikethrough Pixels*

In case of Strikethrough pixel the substrates used for all the samples were same and the liquid ink was used. The porosity of strikethrough sample is 6 sec and the thickness is 0.059mm.

Conclusion

Image quality can be degraded if showthrough or strikethrough pixels merged with the background and as well as foreground image. So this is a very much important task to detect this kind of print defect and remove it in terms of quality control of print job. Generally this defect detection is done manually in press which makes the job very much time consuming and dependent as this varies with man to man ability of detection. So it becomes a popular research direction to detect these defects with the help of image processing tool that can be less manual and less time consuming. As the showthrough and strikethrough are almost same type of defects caused by ink penetration or absorption, a common method of detection is proposed in this paper. A major limitation of this study is appearance of scummimg, tinting which make the detection a little bit noisy. Post processing operations can be a solution to overcome this problem. Moreover exploring detection process in different color space can be further extended by reconstructing of image removing the showthrough pixel.

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Bookplate in the context of Ukrainian printmaking at the turn of the XX and XXI centuries: Typological aspect

ABSTRACT

The article is dedicated to the examination of the bookplate of modern Ukraine, which starting from the 1990s entered the state of its revival and flourishing. A version of the bookplate typology, formed on the basis of pictorial motifs as the main classification criteria is proposed, while typologically bookplate is usually divided into groups based on the scope of use or the technique for creating graphic sheets. The reasons for the actualization of bookplate as a type of engraving at the turn of the 20th and 21st centuries, the factors that influenced its popularization outside the country, and the transformation of the functions of bookplate are considered. The role of collecting as one of the most powerful stimuli for the popularization of bookplate in the modern world of graphic arts is emphasized; the leading centers for the development of the bookplate in Ukraine at the beginning of the 21st century and the technique preferred by artists are indicated.

KEY WORDS
Bookplate, ex-libris (EL), woodcut, etching, engraving

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Introduction

In the last quarter of the 20th – early 21st centuries, Ukrainian printmaking, which can be described as a rather ancient but little demanded form of fine art, received a new segment, the development of which proceeded very dynamically and along several vectors at once (Romanenkova, Bratus & Kuzmenko, 2021). While book graphic arts in general can be considered quite popular due to the demand for the book itself and its mass character (Hopkinson, 2011), then the bookplate has long been considered only an auxiliary element having a secondary, applied function, primarily positioning itself as an information holder Bookplate stagnation in Ukraine ended with the beginning of the 1990s, when Ukrainian masters came out of the shadows to the international arena (Romanenkova, 2015). A very active process of artists entering the international art space began, and accordingly, the emergence of new vectors for the development of the Ukrainian bookplate. From an auxiliary element, information holder, a bookplate turns into an independent work of art of a high professional level of artistic performance, which leaves the "shadow zone" and moves into the "zone of increased attractiveness", becoming self-sufficient and acting as an inherently valued phenomenon with artistic worth, an object of exhibition and collection (Mikhalchuk, 2014a). Since 1993, there has been a metropolitan bookplate club (UBC) in the country, headed by the art critic and collector P. Nesterenko, the author of one of the two dissertations that exist today on the bookplate of Ukraine and a number of scientific and popular science studies

about it (Nesterenko, 2012; Nesterenko, 2016; Nesterenko, 2021a; Nesterenko, 2021b). The UBC mostly exists as a "hobby club", being a public organization, and reposes on the enthusiasm of its members. This explains the fact that bookplates in Ukraine are purely commercial, i.e. processes in this area are possible only thanks to the own efforts of artists and critics, and, as the main source, sponsorship of patrons (Romanenkova, 2021).

Artistic centers, main representatives, dominant techniques of modern Ukrainian bookplate

Starting from the 1990s, several epicenters of the main processes of bookplate development in Ukraine begin to emerge. The most fruitful are Kyiv (R. Agirba, K. Antioukhin, A. and S. Burtovyy, V. Vyshnyak, R. Vygovskiy, Yu. Galitsyn, Yu. Kamenetskaya (Kamenetska, 2019a; Kamenetska, 2019b), V. Lopata, A. Melnikova, O. Miklovda, A. and G. Pugachevsky, N. Stratylat, V. Taran, A. and S. Kharuk (Romanenkova, Paliychuk & Mykhalchuk, 2021)), and Lviv (O. Hnatyv, O. Denysenko, B. Drobotyuk, S. Yvanov, Ye. Kozanevych, R. Romanyshyn, S. Hrapov) schools. Less massive in terms of the number of prominent representatives, yet no less interesting are Odessa (D. Becker), Kharkiv (N. Neimesh), Chernivtsy (O. Kryvoruchko), Sumy (V. Lomaka), Lugansk and the Lugansk region (K. Kalynovych, B. Romanov), Dnipro (S. and V. Khvorost), where one can talk about traditions and demand outside the country, but it is too early to talk about the school.

At many prestigious competitions, Ukrainian bookplates received the highest awards, won prizes, some of them were recognized by leading professional associations of bookplate creators and collectors (Mykhalchuk, 2021). First of all, this refers to the representatives of Kyiv, Lviv, Lugansk. Historically, Lviv craftsmen were famous for their bookplate created using gravure printing techniques. Most often they turn to either pure etching or a combination of several techniques, whose tools are similar, and the visual effect is enriched by this synthesis of mezzotint, soft varnish, aquatint, dry point (Romanenkova et al., 2021). Resist, engraving on steel are less widespread. The palette is predominantly laconic – etching by Lviv people and representatives of other Ukrainian bookplate schools, is monochrome, color etching (and in combination with other techniques) is quite rare (Lviv expert R. Romanyshyn, Kyiv master K. Antioukhin). Sometimes, for example, watercolor or gouache tinting of etching is used, which leads to an enrichment of the palette and a change in the perception of texture (Lugansk graphic artist K. Kalynovych). Today copper and steel are used less frequently. Steel can generally be called an exception – it is very difficult to work with, technologically few people can operate it, the process is incredibly laborious, and the stroke is quite dry and sharp.

Kyiv masters often become known in the professional environment for their work in xylography techniques. While a few decades ago woodcuts (both end and edged) dominated, for which different types of wood were used, including boxwood, exquisite in texture, then at the beginning of the 21st century wooden boards were almost universally replaced by a synthetic base, i.e. plastic of different thicknesses. The linocut, which is very common among artists since their youthful experiments, does not lose popularity due to the malleability and availability of the material. At the same time, it was the inaccessibility and costliness that caused the artists to almost completely abandon the use of boxwood, which, moreover, is difficult to work with and is one of the most solid foundations in woodcuts.

Ex-librists rarely appeal to flat printing, because the specifics of lithography do not allow them to comfortably work in small forms, so using this technique to create a bookplate is not very rational (Mykhalchuk, 2014b).

Criteria for the classification of the Ukrainian bookplate of the last third of the 20th – early 21st centuries

Based on the functions of a bookplate, we distinguish artistic and utilitarian, applied, i.e. works of art and information holders, which are also subject to classification. It is noteworthy that in this case only artistic bookplate is a matter of discussion. The classification criterion can also be the location of the bookplate in the book. Thus, the super bookplate, placed on the spine or cover of the book, namely in its initially visible zone to the viewer becomes an independent type. But if we keep in mind that in recent decades the bookplate, having transformed from an ordinary information holder into a work of art, is no longer dependent and acquired an independent life as a work of small-form graphic arts OUTSIDE of the book, this criterion ceases to be effective and is applicable only to bookplates created before a certain period.

Artistic bookplates are often divided into subject, monogram and stamp. However, this classification is not entirely correct since the fantasy of modern artists often leads to a synthesis of different types of works, when the coat of arms becomes part of a complex, already thematic composition (Spivak, 2010). The same can be said about the initially classified as monogram bookplates.

The criteria are also the techniques in which bookplates are created (Safonova, 2011). Based on this, it is possible

to single out bookplates created in the techniques of xylography, intaglio and flat printing, bookplate created using computer graphic arts. Sometimes, graphic sheets created using a complex embossing technique, which is mastered by an extremely small number of experts, are singled out as an independent group. Embossed or textured, the so-called blind embossing is a technique, the complexity and ambiguity of the effect of which is dictated by the features of use. It comes to colorless embossing, which is perceived in a very specific way, and more often it is used not as an independent technique, but as an addition to the main ones. It can be combined with embossing, such as foils, if a master has a sufficient level of professionalism for a clear alignment when printing plates. Very often, it performs the stamp of the author of the composition, the author's monogram or logo, if it is present in the graphic sheet.

The color characteristic is also used as a classification criterion, i.e. black and white and color bookplates are distinguished. It is not correct to talk about which of the groups is more in demand and numerous, as it is almost impossible to obtain data of this kind. One can only trace the tendencies of dominance locally, in certain geographical segments and applicable to individual chronological periods. For example, for the Lviv school of modern book sign, a monochrome and black-and-white manner is somewhat more typical, if we take as an argument that the Lviv people are strong in intaglio printing, and etching, as noted above, is more often monochrome. At the same time, Kyiv masters of xylography techniques bring their bookplates to a virtuoso level of performance, turning to polychromy in plastic engraving: they are very popular in Belgium, Italy, Portugal, and other countries (Belgrade Ex-Libris Circle, 1995b), for example, multi-color book plates by Kyiv artists A. and G. Pugachevsky, some of which are made in six, eight, ten and sometimes more plates.

Modern Ukrainian art bookplate: Dominant pictorial motifs

Thematic bookplates can be divided into separate group. It is worth highlighting that group of bookplate that are plotless, *abstract*. Of course, monograms, fonts, ornamental stamp compositions always stand apart, regardless of the color characteristics and performance technique. But abstract ones also deserve special attention. They are convenient since they are universal, they can suit any customer who does not limit the artist in any way. Stylization, allegorical language are inherent in almost all bookplates, but here they are reduced to the Absolute. In such works, the main focus of the viewer's attention is on the composition, technique, stroke, palette features.

The array of *allegorical* bookplates is also quite large. A bookplates always tends towards conventionality and symbolism, so the language of allegory is much more appropriate for it. Masters of different schools turn to allegory (Lugansk artist Kalynovych K.: “The Eternal Temple of Knowledge”, etching, dry point, 2020; Pugachevsky G. from Kyiv: “Ex-libris George Mulders. “War and Peace”, plastic engraving, 2000). Representatives of the Lviv school of ex-libris are very indicative in their inclination towards a complex allegorical artistic language. Many complex graphic sheets in etching techniques were created by O. Denisenko, S. Ivanov, S. Hrapov. O. Denisenko can be attributed to the cohort of the most sought-after Lviv ex-librists, who works in intaglio printing techniques and uses the complex language of allegory, which creates a kind of artistic code of his works. Bookplates by Denisenko are monochrome, often in black and white, i.e. color is not an instrument of influence on the consciousness of the viewer, therefore, a compensatory mechanism is used to achieve the goal – the language, the code of the pictorial motif, namely, allegory, stylization, complexity from the point of view of technology (Figure 1). A common theme in the artist's bookplate is the image of a knight, which varies in many works, and not only in bookplates.

Portrait bookplate is also quite common. The portrait image, both stylized and naturalistic, can act as a central element of the plot composition of works of other genres, dominating from a compositional point of view (Pugachevsky A.: «“Ex-libris Y. Berdichevsky. “Pushkin in Kyiv”», plastic engraving, 2002; Pugachevsky G.: «“Ex-libris Marietta Hagedorn”, “Copernicus”», plastic engraving, 2009), and be the main segment of the graphic sheet (Kalynovych K.: “Ex-libris E/A for Arnold Hausweiler”, etching, 1991; Kalynovych K.: «“Ex-libris Johnny Mann. “Portrait of C. Slani”», etching, 2018, Figure 1; Pugachevsky A.: «“Ex-libris Biblioteka Comunale Di Lomazzo. “Sandro Botticelli. 1510-2010”», plastic engraving, 2010; Romanov B.: “Ex-libris S. Demin”, linocut, 1998). Stylization is not so distinctive for this type of bookplates.

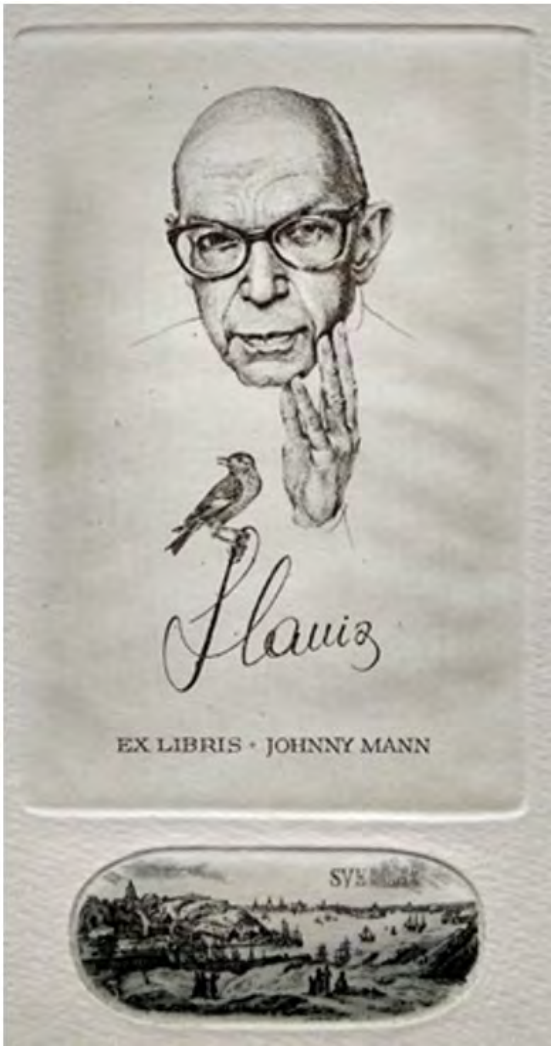
Ex-librists often turn to architectural motifs, which determine the pictorial dominant of their graphic sheets, when one can speak of a kind of *urban* bookplate. The core of the compositions often become monuments of religious architecture, but emphasis is also placed on secular buildings. Geometrism dominates in such bookplates, when the building is the main dominant, and not the staffing. Buildings can be stylized, depicted in silhouette, spot (Romanov B.: “Ex-libris K. Motrich”, linocut, 1993), conditionally schematically, in a generalized way, conveying the general idea (Luchko V.: “Ex-libris V. Hetirer”, linocut, 1993; Pugachevsky A.: «“Ex-libris G. Blum. “There are many religions – God is one”», plastic engraving, 1994; Pugachevsky A.: «“Ex-libris H. Stopikowski. “Domes of Moscow”», plastic engraving, 1993; G. Pugachevsky: «“Ex-libris H. Pungs.

"Old Street"», plastic engraving, 1995), but there are also quite naturalistic images, the purpose of which is recognizability of the building (Saratovsky I.: "Ex-libris B. Zhelekhivsky", linocut, 1993; Pugachevsky G.: «"Ex-libris Cor van Vlijmen. "Amsterdam"», plastic engraving, 1997; Pugachevsky A.: «"Ex-libris Ivo Prokop. "Kyiv-Pechersk Lavra"», plastic engraving, 1996; Pugachevsky A.: «"Ex-libris S. Brodovich. "St. Andrew's Church"», plastic engraving, 2006), Pugachevsky A.: «"Ex-libris (P). Van Os. "Malbork Castle"», plastic engraving, 1993).

» **Figure 1:** *Denisenko O. «"Ex libris Aloys Vertongen. Horn"», etching, 1999.*

Literary bookplates are in great demand among bibliophiles. It is popular not only periodically, when competitions are held to coincide with anniversaries, but it constantly attracts the attention of collectors. Graphic sheets with portraits of writers are created (Kalynovych K.: "From the books of Sergei Lishchyna", etching, 2014), often accompanied by the characters of their works. Among the favorites of artists are A. Pushkin, V. Shakespeare, M. de Cervantes, T. Shevchenko, M. Bulgakov, V. Vysotsky. Quite often, bookplate subjects are drawn from fairy tales (Pugachevsky A.: «"Ex-libris Yan Liu. Hans Christian Andersen. "Thumbelina"», plastic engraving, 2008; Pugachevsky A.: «"Ex-libris Yanying Guo. "Cinderella"», plastic engraving, 2008), folklore.

Such a bookplate is a kind of visualization of the blurring of lines between genres since it adopts all the characteristics of a book illustration (dozens of book sheets of Shevchenkiana by B. Romanov; Kalynovych K.: «"From the books of N. Tserkovny. N. Gumilyov. "Lost Tram III"», mixed technique, 2014; Agirba R.: "Ex-libris Fu Xian Zhai – 30. Don Quixote Serenade", etching, aquatint, mezzotint, 2012; Agirba R.: «"Ex-libris P. Becker. "Don Quixote"», plastic engraving, 1997; Agirba R.: «"Ex-libris MT&R. Brondolo. "M. Bulgakov. Dog's Heart"», plastic engraving, 2009; Pugachevsky A.: «"Ex-libris Luc van den Briele. "Gargantua and Pantagruel"», plastic engraving, 1994; Pugachevsky A.: «"Ex-libris Yaoshen Fang. "Don Quixote"», plastic engraving, 2009, Figure 3; Pugachevsky G.: «"Ex-libris George Sekine. "Don Quixote"», plastic engraving, 1999) (van den Briele, 1994).



» **Figure 2:** *Kalynovych K. «"Ex-libris Johnny Mann. "Portrait of C. Slani"», etching, 2018.*

Sacred bookplates can also be attributed to the most popular in the Ukrainian bookplate (Soborna Ukrayina, 1994). Religious themes have gained rapid popularity since the 1990s, when compositions depicting architectural shrines, scenes from the Old became popular (Kalynovych K.: «"Ex-libris S. Brodovich. "Judith"», etching, 1993; Pugachevsky A.: «"Ex-libris PE vd Velde-Rath. "Moses"», plastic engraving, 1996) and the

New Testament (Antioukhin K.: "Ex-libris SJM", etching, aquatint, 1994), individual personalities of sacred texts (Pugachevsky G.: «"Ex-libris Werner Grebe. "St. Ursula"», plastic engraving, 1997; Pugachevsky G.: «"Ex-libris Hermann Wiese. "St. Sebastian"». plastic engraving, 1996). From the Old Testament, there is the exploitation of the images of Adam and Eve, which are also played out in connection with specific plot collisions (Kozanevych Ye.: "Ex-libris Warwarow A.", etching, aquatint, 1993; Pugachevsky G.: «"Ex-libris Joop Sliep. "Adam and Eve"», plastic engraving, 1995; Pugachevsky G.: «"Ex-libris Hildegard Pungs. "Adam and Eve"», plastic engraving, 1995; Pugachevsky G.: «"Ex-libris L.A. Aarsen. "Adam and Eve"», plastic engraving, 1996; Pugachevsky G.: «"Ex-libris Birgit Gobel. "Adam and Eve"», plastic engraving, 1998; Taran V. "Ex-libris Antonio Gomez", linocut, 1993) and in a more generalized context as symbols of love, flirting, temptation.

» **Figure 3:** *Pugachevsky A. «"Ex-libris Yaoshen Fang. "Don Quixote"», plastic engraving, 2009.*

The most common of the New Testament personalities are Jesus Christ and the Mother of God (Romanov B: "Ex-libris V. Dolinovskaya", plastic engraving, 1993; Lomaka V. "Ex-libris P. Nesterenko", plastic engraving, 1993; Taran V.: "Ex-libris B. Gavrylyshyn", linocut, 1993), angels (Mykhalchuk, 2017). While the Christ and Mother of God cycles involve certain difficulties with often multi-figure composition, and therefore only very experienced highly professional artists can apply to them, then the angel can also vary in multi-figure compositions, and be a single figure in a graphic sheet (Galitsyn Yu.: "Ex-libris R. Jurelionio", plastic engraving, 1993). The angel is a head turner for an artist who knows how to stylize well; such bookplates usually have a high degree of musicality, elegance, gracefulness of rhythm. Among the illustrative examples is the bookplate of the work of the Kyiv graphic artist G. Pugachevsky (Pugachevsky G.: «"Ex-libris B. Junod. "Angel"», plastic engraving, 1994, Figure 4), created in nine (!) plates, where unique polychromy is combined with exquisite stylization and musical poetry of the image, which could not go unnoticed by the judges of the competition: the work of the young artist was awarded a Medal at the Sixth International Biennale of Small Forms and Bookplates in Poland in 1995.

» **Figure 4:** *Pugachevsky G. «"Ex-libris B. Junod. "Angel"», plastic engraving, 1994.*

Mythological ex-libris compositions by Ukrainian graphic artists are also in demand among collectors – extremely beneficial freedom from canons and plot restrictions, the possibility of free interpretation of images and frequent exploitation of the "nude" motif attracts masters to this category of subjects (Belgrade Ex-Libris Circle, 1995a). They also include ancient mythology ((Pugachevsky A.: «"Ex-libris S. Brodoych. "Centaur and Lady"», plastic engraving, 2007; Pugachevsky G.: «"Ex-libris Emil Kunze. "Icarus"», plastic engraving, 1998; Pugachevsky G: «"Ex-libris N.H. (Norbert Hillerbrandt). "The Birth of Aphrodite"», plastic engraving, 1996), and folklore motifs (Galitsyn Yu.: "Ex-libris Bogachevsky Marty, Khomyak Rostislav", plastic engraving, 1993) and ancient Slavic

legends (Zastavnaya I.: “Ex-libris Lesya Rilkova”, line zincography, 1993), and plots from ancient literature (Agirba R: “Ex-libris Zheng Shiting. “Medea”, etching, aquatint, mezzotint, 2012; Sivak A.: “Ex-libris Mario de Filippis”, linocut 1993), where the core is built around the myth, the spectrum is very wide. More often, variations of “The Ravishment of Europe” can be met (Agirba R: “Ex-libris I.P.P. Giannakos-Xotaris”, etching, aquatint, mezzotint, 2012; Pugachevsky A.: “Ex-libris S. Brodovich”, plastic engraving, 2007; Pugachevsky A.: “Ex-libris Harmut Opperman”, plastic engraving, 2003”, Pugachevsky A.: “Ex-libris Ya. Berdichevsky”, plastic engraving, 2007), “The Judgment of Paris” (Agirba R : “Ex-libris Dr. Peter Labuhn”, plastic engraving, 2008; Pugachevskiy G.: “Ex-libris P. Labuhn”, plastic engraving, 1995), “Leda and the Swan” (Agirba R: “Ex-libris S. Brodovich”, etching, aquatint, mezzotint, 2004; Agirba R: “Ex-libris R. Agirba”, etching, aquatint, mezzotint, 2013; Pugachevsky A.: “Ex-libris Futian Li”, plastic engraving, 2009).

In a separate category, a very numerous one, one can single out those bookplates on mythological subjects that have an erotic connotation (Soborna Ukrayina, 1993). Nude figures often occupy the main place in mythological compositions; compositions can also have a pronounced erotic character. However, nude images can be the center of ex-libris compositions on other topics, female personalities are one of the most exploited by artists. Therefore, it is more correct to single them out in a special category and conditionally designate them as *lyrical* since the theme of erotica in a bookplate is popular, yet more local (Antioukhin K.: “Ex-libris Pieter Jonker”, etching, aquatint, 1995.; Agirba R.: «“Ex-libris Ludek Kriz. “Young wine”», etching, aquatint, mezzotint, 2017). Amorous, romantic plots are constantly found in the bookplate of all periods. The “nude” motif can be played very elegantly outside the plot, when female images of a conventional, generalized nature, with varying degrees of stylization, become the center of the composition (Miklovda O: “Ex-libris Heikki Lahi”, cut woodcut, 1993; Gnativ O.: “Ex-libris Mario de Filippis”, linocut, 1993). But more often we can see numerous plots glorifying lovers, as the book sign was no exception in the host of art genres that sing an ode to female beauty and the elements of love (G. Pugachevsky: “Ex-libris S. Brodovich”, plastic engraving, 2004).

Conclusions

Many bookplates created by modern Ukrainian artists are difficult to classify. They may contain elements that allow them to be classified into several categories at the same time. Therefore, there is no unambiguity in any variant of the typology. There are also many bookplates, the dominant pictorial motif of which was images of a fool, clown, circus scenes, a lot of animalistic graphic sheets, bookplates-cartoons, many works depicting the signs of the zodiac. Thus, there are a number of pictorial motifs that are not included in the above-mentioned categories since only those that can be called the most extensive due to the demand for the plots and motifs underlying them stood out. There are also motifs that have lost their relevance in the Ukrainian ex-libris, so they can only be considered in the context of an analysis of a bookplates of an earlier period, such as sheets with symbols and plot dominants of the Soviet era. Since the 1990s national motifs replaced them. These motifs were exploited very often, which emphasizes the dependence of this art form on the realities of the time and underlines the fact that the bookplate is a kind of miniature mirror of the era, clearly reflecting its trends and the dynamics of historical and cultural processes.

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MTC: Visualization method of assessing physical movements with dribbling performance of basketball based in 3D Space

ABSTRACT

We present a basketball training visualization method – Motion Time Cylinder (MTC) designed to help novice players learn basketball techniques more easily. The basketball player can select their preferred movement to learn and visualize the body and joint movements in detail. Extensive visualization as a graphical assistant help supports the player in understanding 3D movements from the visual patterns. At the same time, players can understand the coordination and spatial relationship when playing the movement. The visualization principle is based on the mapping of body movement into the graphic of clock-based division locations. The movements can then be represented by the translation pattern between the frontal and transverse planes of cylinder spaces. As a result, the movement can be visualized by rendering the translation pattern base on the clock from a specific perspective, for example, an orthogonal view. This paper explains the visualization principles of the mapping and pattern as well as the graphical representation based on user perception.

KEY WORDS
Basketball training, visualization method, motion capture, body movements, graphical representation

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Introduction

Basketball is one of the most widely practiced sports in the world, with over a billion participants worldwide. In a basketball game, not only the overall structure of an organization is demonstrated but also the tactical requirements, collaboration, timing, expertise, and level of physical fitness of the players on the court (Chiou, 2001). The majority of coaches believe that shooting is the most significant ability in basketball, but dribbling should be the first aspect of the game to be taught (Chi-Yang et al., 2006). Dribble is one of the fundamental offensive skills that encompasses a variety of performance forms (dribble with a change of direction, dribble hesitation, crossover dribble, inside and outside dribble, behind back dribble, dribble with pivoting and rotation, etc.) (Moselhy, 2020). Dribbling is defined as penetrating the ball while moving toward the basket and improving the passing angle. On the other hand, the dribbling technique is quite challenging to execute (Patel, Pandey & Bhownik, 2021). There have many detailed movements in the muscle and bones when the ball interacts with the ground and hands that require the player to perform high-level abilities of agility, motor control and manipulating the ball with fast-moving (Liu & Hodgins, 2018). It is crucial to have an effective dribble to be successful in any offensive strategy, especially if players are fast and defenders cannot stop them from shooting or cutting the ball off (Moselhy, 2020). Therefore, this skill requires players to maintain a higher level of physical balance and body coordination (Lu & Wei, 2021). It is necessary to visualize the movements and coordination of players who dribble from 3D to graphic visual spaces, which benefits novice players more visually by observing their body posture while dribbling and comprehending the complex body changes in basketball training. With the advancement of technology, numerous researchers have utilized motion capture systems to objectively analyze

the basketball skill performance of players (Li, Rupčić & Knjaz, 2021). The term "Motion capture" refers to the process of recording motions and translating them into a digital representation (Pullen & Bregler, 2002; Müller & Röder, 2006). If we can visualize the digital model of motion capture, the characteristics can be discerned immediately. It is possible to use motion data visualization to aid in recognizing and analyzing human motion patterns (Hu et al., 2010). In this context, the main aim is to analyze and visually represent various basketball dribble variations in a visual graphic. Motion data can be visualized, which helps novice players understand dribble movement more quickly and clearly. (Hu et al., 2010). For example, the NBA carries out game motion tracking and data visualization and analysis by sportsVU, which converts data to video to provide advanced statistics for motion-tracking data, including the number of shootings, the average distance between defenders and the average speed (Yu & Chung, 2019).

Although previous work has explored sports data visualization to help basketball sports analysis and training, the research gap we emphasized is that most of the current research has focused on shooting, such as the success rate of the basketball free throw or the biomechanical analysis of the jump shot. Few researchers have examined the movements and coordination of basketball dribbling. Lots of studies focused on the detailed visualization of body movements and coordination. However, that makes the visualization principles and graphical representation complicated and not easy for non-research, for instance, teenage basketball novice players, to understand during training. It gives rise to the importance of an expressive graphical representation based on the design for user perception to visualize the changes in body coordination of a player during basketball dribbling in a visual space with extracted features. The design and definition of an effective visualization principle of dribble movement are needed.

In this paper, we present Motion Time Cylinder (MTC). This novel visual space visualization approach helps extract key dribble motion features and exhibits variations in the player's body movement, which shows the different movement orientations. Furthermore, we have collected basketball dribble data from the Optical Motion Capture (OMC) system. These data allow us easy to understand the meaning of a basketball motion and measure the movements even though the dribble skills are complex.

To summarize, we have made the following contributions to this paper:

- We first use OMC to acquire motion data for various basketball dribbling movements based on human joint hierarchy.
- We propose the MTC system as a novel visualization approach and separate the orientation movements of specific body parts.
- Based on the complex and subtle movement of different body parts, convert the 3D motion patterns to MTC visual representation.
- Defining rules between patterns and motions to help novice players for better perception during basketball dribbling.

The structure of the paper is as follows: Section 2 discusses the related works on various kinematic analyses for basketball and sensing technologies in motion capture. Section 3 details the body coordination changes in 3D and the data collection system. Using the collected data, we show the method of MTC visualization on the ongoing basketball dribbling example in section 4. In the end, we conclude with a discussion of potential future work.

Related works

When players hold the ball in their hands and prepare for their next movements, they have three options in mind: dribbling, passing, and shooting (Arias-Estero, 2013). In the offensive action, players with proficient dribbling techniques are able to execute a variety of dribbling movements to break the defense of opponents, which paves the way for teammates to have more score opportunities (Arias-Estero, Argudo & Alonso, 2012; Arias-Estero, 2013). Conte et al. (2016) pointed out that effective dribbling skills play a vital role in a successful basketball game. Dribbling in the correct postures and angles can help reduce movement errors and increase the percentage of games won.

The impact of basketball skills on kinematics has been studied by researchers in the past. Iacob et al. (2014) discovered the correlation between the optimal arm and hand flexion during free-throw basketball. Their research revealed kinematic analysis regarding free throws under the basket and determined the angular motion velocity of each joint segment of the arm during the shot. This study significantly improved the shooting opportunities for players. Patel, Pandey & Bhownik (2021) discovered significant correlations between particular angular dynamics variables at the time of preparation for high dribble. Furthermore, they demonstrate a statistically significant relationship between high dribble performance and the right joints, such as the right hip, ankle, wrist, etc., during moment preparation and execution. However, to the best of the author's knowledge, no previous research has explored the visual changes of different basketball dribbling kinematics.

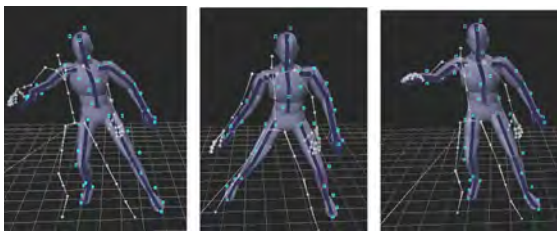
Humans have developed numerous techniques for representing motions in graphical and visual forms, allowing the audience to comprehend the nature of motion eas-

ily. Motion capture is practical and flexible in that data can be captured for any motion deemed essential to the research project. In addition, the data can be easily manipulated in terms of sample size and duration. Consequently, numerous research teams work with full-body motion capture and data visualization (Li, Bartram & Pasquier, 2016). Liu & Hodgins (2018) presented a method for achieving robust control of the basketball ball movement and coordinated arm motion from input motion capture data based on trajectory optimization and deep reinforcement learning. Their framework learns various static control graphs of basketball dribbling skills as reference motions to facilitate the basketball technique learning and interaction with simulated players for users. Furthermore, Starke et al. (2020) proposed a framework based on mixture-of-experts architecture to learn multiple and fast interactions between characters, basketball and environments from the motion capture database. However, these studies cannot be utilized to develop detailed controls for basketball skills. To properly execute the ideal dribbling movement, players must predict and accurately control the ball, hand touch and timing in advance. If coaches rely only on sample collecting and do not develop an awareness of strategy and analysis for players, they cannot perform such tasks effectively.

Balasubramanyam et al. (2020) proposed a MotionSphere, a trajectory-based visualization technique on the surface of a unit sphere, to represent human motion. The players are rendered as 3D avatars and visualized subtle motion as swing trajectories and twisting motion with color-coding. However, the work is concerned with the simpler actions compared to the high-speed movement of basketball and no visualization of the complex and high-speed motion data is shown as part of that work.

Visualizing body coordination changes in 3D

In this study, the OMC system is used to capture the variations in the player's body coordination during dribbling. As shown in Figure 1, these body coordination changes are translated into digital models and presented in 3D space.



» **Figure 1:** *3D full body skeleton model*

Motion tracking system

The OMC system is essential for human motion synthesis and analysis. In motion analysis, researchers use motion capture data to evaluate specific aspects of muscle and bone (Guerra-Filho, 2005). Specifically, the rubber balls are covered with reflective material and affixed to the specific joint location of players throughout the capture procedure. The cameras are calibrated to precisely receive light sources at a specific threshold and precisely capture the light source reflected from the rubber balls instead of other light sources, such as the light reflected off the skin (Estévez-García et al., 2015).

Researchers use 20 Optitrack cameras (Prime13) with a 90Hz sample rate to record the basketball dribbling motion into 3D data. Motive software is utilized to label the motion 3D coordinates, including the horizontal, vertical, and forward axes. Finally, researchers clean the data and export time series to analyze motion variables.

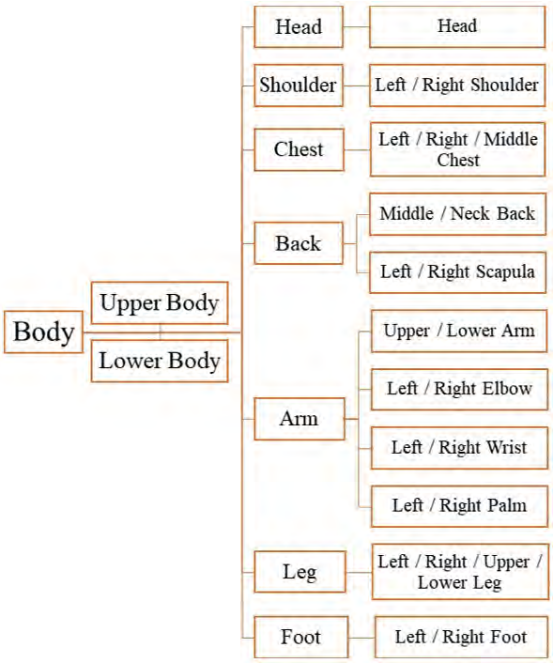
In this process, as shown in Figure 2, players wear tight-fitting black suits and are affixed with 44 reflective rubber balls as markers. These markers are placed on rigid parts of the body, including the head, shoulders, arms, back, pelvis, legs and feet.

» **Figure 2:** *The position of markers on rigid parts of the body*

Body hierarchy

As shown in Figure 3, the skeletal changes in human movement are hierarchical movements in which joint-bone segments have a parent-child relationship. This paper uses hierarchical modeling to visualize the posture and body coordination of basketball players. In the skeletal study of sports, the human body is typically considered as a skeleton tree formed of rigid bodies. Specifically, different hinges connect adjacent bones to each other to construct the skeleton tree. There is a parent-child relationship between the skeletons, with the child node skeletons rotating around the parent skeleton (Nie et

al., 2021). It is possible to isolate “illustrable” portions of a skeletal motion capture sequence using a hierarchy. With this method, the basketball dribbling motion can be illustrated at the different specified joints.



» **Figure 3:** *A skeleton tree of human motion capture data*

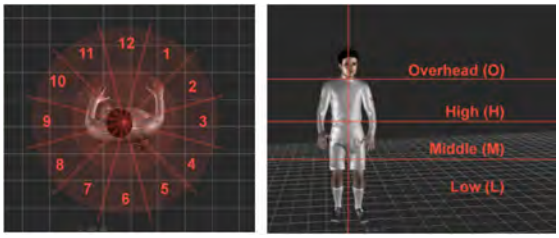
Visualization principles

The relationship of the direction, position pattern and the actual variations of the body coordination must be precisely defined and understand how the direction and position pattern represent the motions during basketball dribbling. Two planes are applied to relatively divide the surrounding movement space to define the rule between the pattern and the actual motion. All body parts are placed in a unit cylinder and can be divided into frontal and transverse planes around the players.

Motion Time Cylinder (MTC)

MTC is a novel visualization method based on user perception. It provides a visualization of the arm swing associated with basketball dribbling by clock motion and the joint position, as shown in Figure 4. Mapping the joint movements in a unit cylinder graphic, MTC represents variations in body direction and position when the players dribble the ball. MTC adopts different visual patterns to analyze body variations for players based on the frontal and transverse planes. The players' body direction and position variations are labeled on a cylinder of 12 equal parts. From the top-down view, the transverse plane based on the clock visualizes the variations of the players' arm swing translational.

The frontal plane on the cylinder represents up and down variations of arm swing movement of players during dribbling. MTC enables players to perceive movement variations during basketball dribbling.



» **Figure 4:** *MTC visualization method*

Movement in MTC

The changes of direction (CODs) for body coordination and arm swing are key movements linked to decisive moments in basketball dribbling. Players need to perform a diverse range of CODs, from various angles; the ability to change dribble direction safely and quickly by arm swing is essential (Dos’Santos et al., 2018).

Transverse plane - position

The transverse plane of the body coordination changes for the player is divided into left-right and front-back movements and visualized as a clock graphic. Mapping time distribution on the unit circle help quantifies and visually analyze entire body motion and bone joint movements for players. Moreover, learning movements through clock distribution helps players easily understand arm swing and body movement changes during dribbling.

Frontal plane - direction

Height measurement is attached to the frontal plane of a unit cylinder to visually identify the joint movements up and down and longitudinal orientation variations. The body height and arm swing are divided into overhead, high, middle, and low zones from above the shoulder to below the knee. The frontal variation can be expressed as 4 zones to identify the direction of up and down movement of the arm swing in visual space. This method of representation has the advantage of being able to help the novice player to understand the changes of the body while dribbling in a simple way, even if it is a complex and high-speed basketball movement.

Visualizing the position and direction of swing motion

Due to the coordination and body hierarchy movement during the basketball dribbling, the inverse kine-

matics (IK) is presented based on the shoulders and elbows as the parent node stabilizes the wrists and hands as the child node. IK explains how to control the different joints of the arm to achieve the desired end-effector position change, which is critical to arm swing analysis, such as the child node moving around the parent node and providing motion direction to the parent node (Zhang & Hannaford, 2019). This paper focuses on describing the direction and position variations of the arm swing, which helps to provide basic instruction to novice players. So, in this example, we only describe hand position changes to help novice players understand dribbling skills more easily.

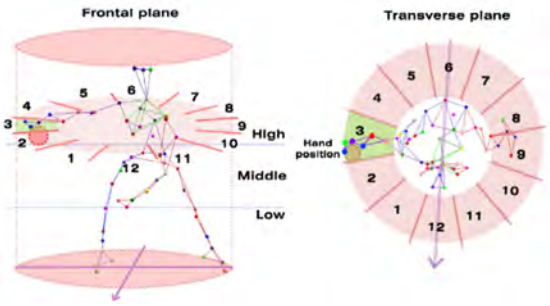
The proposed Motion Time Cylinder (MTC) is evaluated using professional basketball dribble data from the OMC system (involving position and direction changes with the hand). The low stationary dribble exercise, running dribble drill and defense are examples in this study.

Low stationary dribble exercise

The low stationary dribble is a cyclical task that mainly includes seven phases: right hand touches the ball (position); right hand pushes the ball (direction); bounce position; left hand receives the ball; left hand pushes the ball; bounce position; right hand receives the ball. A standard basketball dribble style is established. Participants are instructed to stay tall and look straight ahead for the duration of the dribble.

First step - right hand touches the ball

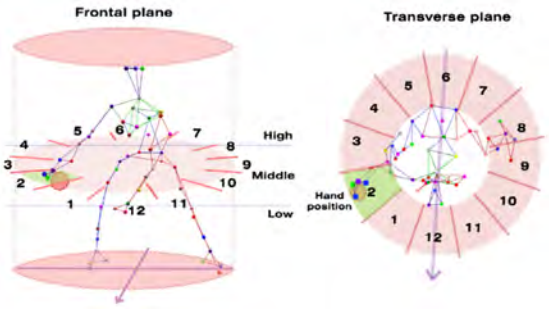
As shown in Figure 5, the player starts the first action of dribbling. From the transverse plane of the MTC system, the right fingertips grip the ball at 3 o'clock. From the frontal plane, the right hand position is at the high zone above the waist. Using the clock and body positioning allows novice players to quickly understand the hand position of the first action when dribbling the ball.



» **Figure 5:** *Right hand touches the ball*

Second step - right hand pushes the ball

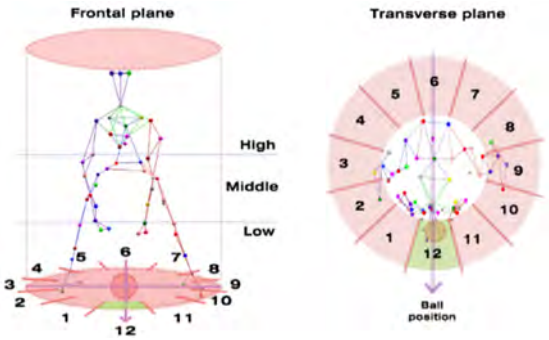
When the player pushes the ball to the floor while moving their hand and the elbow up and down, as shown in Figure 6, the right hand begins to push the ball counterclockwise in the direction from 3 o'clock to 2 o'clock. From the frontal plane, the player moves the hand from the waist in the high area to the knee position in the middle area. Novice players can understand the distance and direction changes of the hand and arm pushing downwards when dribbling the ball.



» **Figure 6:** *Right hand pushes the ball*

Third step - the ball bounce position

As shown in Figure 7, when the ball touches the floor, the hand temporarily loses contact with the ball at the lowest point during the dribbling cycle. Right and left hands naturally drop and maintain the same width as the shoulders. From the frontal plane, the hand from the knee position in the middle area to below the knee in the low area. At this position, the player needs to land the basketball at 12 o'clock.

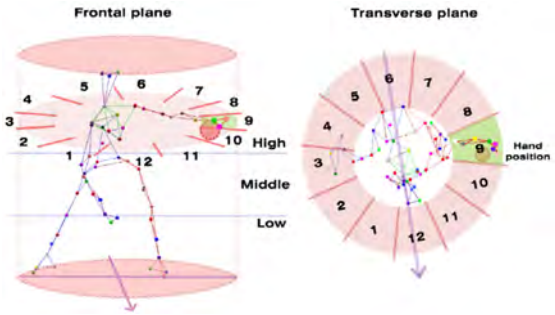


» **Figure 7:** *The ball bounce position*

Fourth step - left hand receives the ball

As shown in Figure 8, when the ball is transferred from the right-hand to the left-hand, at the same time, the player moves his left arm and hand upwards to receive the ball with fingertips at 9 o'clock and the hand at the highest point during the dribbling cycle.

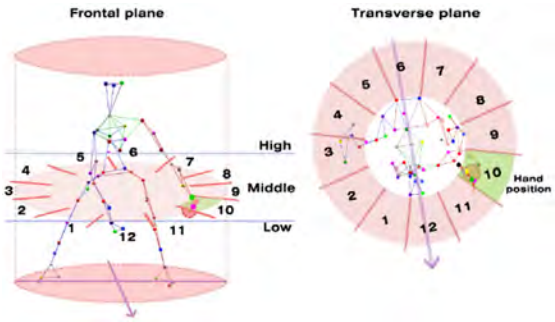
At this position, the left hand is in the high zone above the waist.



» **Figure 8:** *Left hand receives the ball*

Fifth step - left hand pushes the ball

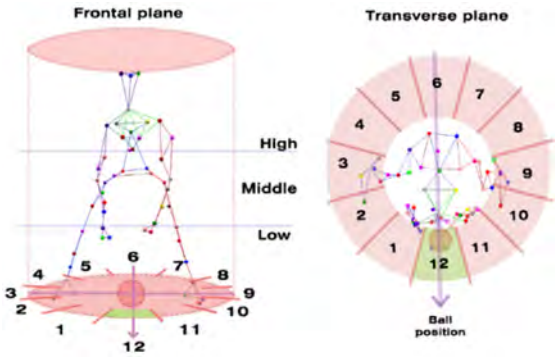
As shown in Figure 9, when the ball leaves the player's left hand, the left arm and fingertips begin to push the ball clockwise in the direction from 10 o'clock to 11 o'clock, and the left hand moves from the outer circle towards the inner circle. From the frontal plane, the player moves the left hand from the waist in the high area to the knee position in the middle area.



» **Figure 9:** *Left hand pushes the ball*

Sixth step - bounce position

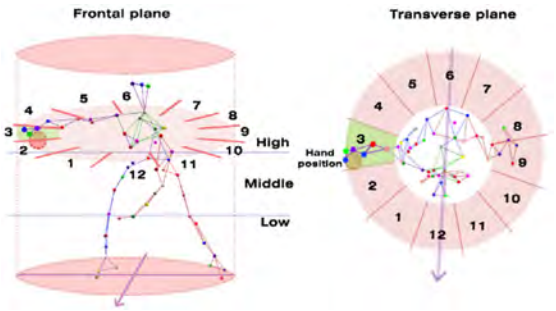
When the ball bounces to the floor from the left hand side, as shown in Figure 10, the right and left hands naturally drop and maintain the same width as the shoulders again and naturally downwards from the knee in the middle area towards the lower area under the knee.



» **Figure 10:** *Bounce position*

Seventh step - right hand receives the ball

The ball received in the right hand represents the end of a complete dribbling cyclical movement. As shown in Figure 11, the ball bounces clockwise off the floor towards the right hand. The right hand drives the wrist and arm clockwise up at the highest height of the dribbling cycle of 3 o'clock again. From the frontal plane, the right hand position at the high zone above the waist again.



» **Figure 11:** *Right hand receives the ball*

Running dribble drill

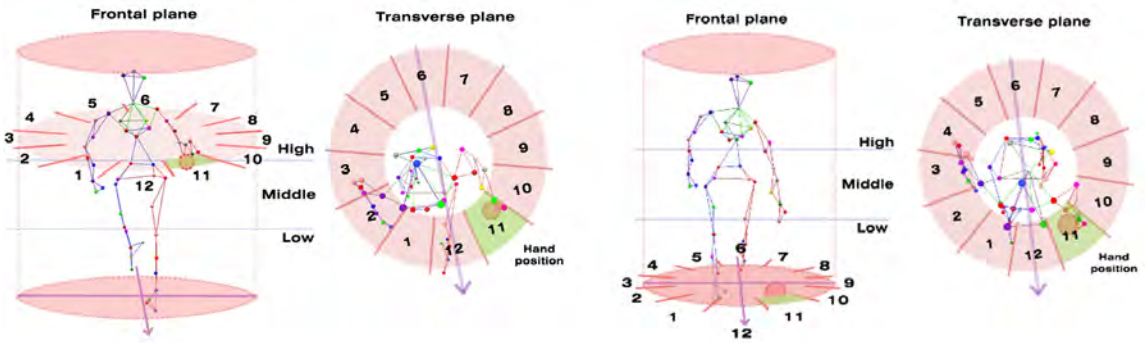
The previous movement has detailed introduced the MTC for individual low stationary dribble. The MTC is expanded in the two movements below to depict running dribble and defense, which enable players to quickly switch between a variety of basketball dribbling techniques.

As shown in Figure 12, when a player is running with dribbling on the court, right fingertips grip the ball at 11 o'clock from the transverse plane of the MTC system. From the frontal plane, the player moves the right hand from the waist in the high area to the knee position in the middle area.

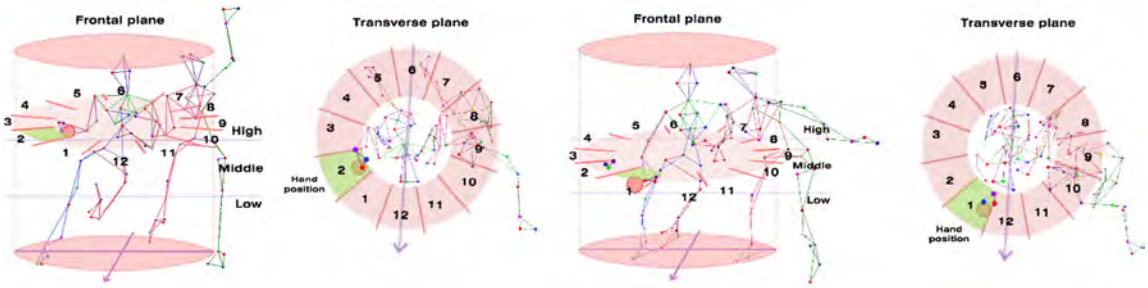
Dribble defense

When the player performs dribble defense drills. As shown in Figure 13, the MTC also can be utilized to help players standardize their arm and hand movements in a competitive atmosphere. From the transverse plane of the MTC, the right arm and fingertips begin to push the ball counterclockwise in the direction from 2 o'clock to 1 o'clock, and the player moves the right hand from the waist in the high area to the knee position in the middle area.

The MTC enables learning basketball to be simpler and makes it easier for novice players to understand basketball skills. Therefore, this method has a wide range of applications in comprehending the details of basketball skills, for example, actions and angles of pushing the ball, swing movements of the wrist, elbow and hand.



» **Figure 12:** *Right hand receives and pushes the ball*



» **Figure 13:** *Right hand receives and pushes the ball*

Evaluation

Participants and procedure

A total of 30 novice players ranging in age from 13- 20 years old attended in our study. We conducted the evaluation by comparing three different online learning methods (basketball coach video, 3D motion video, MTC visualization method). Players observed and learned 10 different dribble movements through three types of online basketball learning methods. At the end of this experiment, all participants used a five-Point Likert Scale (1, strongly disagree; 2, disagree; 3, neither agree nor disagree; 4, agree; 5, strongly agree) to answer a questionnaire survey that evaluate the effectiveness and satisfaction of MTC method in basketball dribbling learning process. The questions of Q1, Q2, Q5, Q8 were used to examined the satisfaction among participants and Q3, Q4, Q6, Q7 were used to identify the effectiveness of MTC. As shown in Table 1, the following is the questionnaire:

Table 1

The questionnaire to evaluate the MTC method

Satisfaction	Effectiveness
Q1: challenging dribbling techniques Q2: enjoyment on instruction methods Q5: visualization method for training Q8: recommendation of methods	Q3: comprehend the methods Q4: effective for dribble learning Q6: detailed dribble techniques Q7: learning dribble movements faster

Results

The purpose of this study is to determine the effectiveness and satisfaction of MTC visualization method in novices' basketball dribbling training. The scores of all participants for each question were summed to determine the combined average score for each question. Descriptive statistics were then calculated for the means and standard deviations to identify the effectiveness and satisfaction of MTC. The higher sample mean (M) score represents greater effectiveness of the MTC visualization method and the lower standard deviation (SD) score indicates higher consistency among all participants.

Table 2

The satisfaction of MTC visualization method

	Q1	Q2	Q5	Q8
M	4.60	4.30	4.20	4.30
SD	0.855	0.750	0.761	0.702

Note. M = sample mean; SD = standard deviation

As shown in Table 2, these four questions were used to test the level of satisfaction with the MTC method. The results showed that novice players were high satisfied with the method when the M scored higher than 4.00. The majority of basketball players believe dribbling is a difficult technique (M = 4.60, SD = 0.855). It is necessary to provide a visualisation method to support the novice player in comprehending dribbling techniques. Furthermore, after the epidemic, players realize the importance of online learning and they like learning skills without traditional coaches by online

methods (M = 4.30, SD = 0.750). The results of questions 5 and 8 indicate that players enjoy training with MTC and will continue to use it with other players in the future (M = 4.20, SD = 0.761; M = 4.30, SD = 0.702).

Table 3

The effectiveness of MTC visualization method

	Q3	Q4	Q6	Q7
M	4.53	4.57	4.67	4.20
SD	0.681	0.728	0.547	0.805

Note. M = sample mean; SD = standard deviation

In aspects of MTC effectiveness, the M results of Table 3 scored higher than 4.00 show that MTC decomposes complex dribbling movements into easily understandable components for novice players and assists players in effectively training dribbling skills. With the MTC method, participants can learn the intricate dribbling movements in detail quickly (M = 4.67, SD = 0.547). Players are given the ability to comprehend the movements through the utilization of MTC, which is a productive method for training in basketball (M = 4.53, SD = 0.681; 4.57, SD = 0.728). Moreover, participants are able to learn dribbling skills more quickly with MTC compared to the other two methods, as indicated by Q7 (M = 4.20, SD = 0.805).

This study demonstrates that MTC visualization method provides participants with a high level of effectiveness and satisfaction when they learn basketball dribbling. The complexity and variety of basketball dribbling techniques present a significant obstacle for novice players. MTC- a simple and easy-to-understand training approach provides players with a great deal of assistance, allowing them to decompose complex movements into simple steps that make it easy for them to comprehend the essential aspects of key movements.

Discussion

Basketball is a flexible and fast sport. Since players differ in terms of skeletal length and flexibility, they all have different skeletal anatomy. In the previous sections, we present a visualization method- MTC, that enables analysis and illustration of basketball dribble movements from motion capture data and is effective for analyzing and visualizing the structural relationships between the joint-bone segments. Different joint and bone localizations are used to describe the motion position. We apply MTC to stationary dribble example of skeletal motion capture data. We successfully illustrate a complex cyclical dribble task using an easier and more intuitive method for basketball novice players.

Compared to complex detail visualization of body movements and coordination, such as precise angles and complex lines, the clock graphic-based can be used to describe the position and direction of the movement, which is the simplest and most understandable way for novice players to observe and train. So that novice players can more easily imitate the movements of professional players and not easily lose interest in training.

Through the basketball training visualization method - MTC, basketball novice players can clearly see the professional basketball player's hand movement during dibbling. With this visualization, novice players will have a clear overview of the overall basketball movements and give a correct evaluation of physical coordination.

Conclusion and future works

Creating a perception-based visualization method for basketball skills is a challenging task. This paper presents a motion visualization system that illustrates basketball training movements extracted from skeletal motion capture data and represents them in a visual space. Our approach analyzes the basketball dribble movements according to the range of time-varying positions and orientations of a body part and applies a number of non-photorealistic motions to illustrate the most important movements. Our method as a motion illustration enables a fast and effective motion analysis to help basketball novice players understand the basketball movements and the difference between two movements.

The current system is a basic functional foundation upon which to build in the future. Although our method at this stage is designed for basketball dribbling skills, we believe that it can be applied to any sports activities in analyzing user motion and help novice users understand other sports in the future. To further extend the proposed method, our goal includes that combine with AI for more precise action recognition and analysis. Motion analysis tools to better recognize behaviors and patterns in motions will be improved and extended to motion recognition by employing different classification methods. We will perform a thorough user evaluation of the MTC method, which will help to define the precise values for this method.

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