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Iris Liveness Detection using Fusion of Thepade SBTC and Triangle Thresholding Features with Machine Learning Algorithms

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Abstract: Conventional security systems are often plagued by inherent flaws, leading to frequent security breaches. To address these vulnerabilities, automated biometric systems have emerged, leveraging individuals' physiological and behavioural traits for precise identification. Among these biometric modalities, iris-based authentication is a highly reliable, distinctive, and contactless method for user recognition. This research endeavours to enhance the accuracy of iris liveness detection by combining features extracted from the TSBTC n-Ary (Thepade's Sorted Block Truncation Coding) method with those derived from the Triangle Thresholding method. Two distinct datasets, namely IIIT Delhi and Clarkson 2015, have been employed to evaluate the efficacy of these combined features. The study involves extracting features from three sources: TSBTC, TSBTC+Triangle, and Triangle methods. These features are subsequently input into the WEKA tool, which employs various classifiers to assess accuracy. The findings of this investigation reveal a notable increase in the accuracy of Iris Liveness Detection (ILD) by incorporating handcrafted techniques like TSBTC in conjunction with the Thresholding method. In essence, this research underscores the potential for improving the robustness of security systems by harnessing the synergy of distinct biometric methods, thereby mitigating the shortcomings of conventional security systems and fortifying the foundations of secure user authentication.

Keywords: Biometrics, Iris Liveness Detection, TSBTC, Thresholding

1. Introduction

In computer vision, the identification of people by their physiological traits. As biometrics doesn't need any external object to recognize the person, instead of an external object, it uses the biological features of the individual.

In contemporary society, human identification methods primarily rely on ID cards, passwords, or tangible objects. However, adopting biometric technology has introduced a paradigm shift by eliminating the need for individuals to carry physical tokens. Unlike conventional authentication methods, which offer no guarantee of genuine user identity, biometrics offers a robust solution. Within a meticulously regulated legal and technological framework, authorities have embraced biometric applications, leveraging them for military access control and civil or criminal identification purposes. Beyond these domains, the domains of banking, retail, and mobile commerce have exhibited a profound interest in harnessing the advantages offered by biometrics [1]. Over the last seven years, thousands of smartphone users have witnessed a surge in awareness and acceptance. They have increasingly turned to biometric modalities such as fingerprint and facial recognition to unlock their devices. The human eye's iris is unique and has some features to identify whether it accurately identifies the human [2]. The texture of the iris remains intact for many decades, and iris recognition has an extraordinary false match rate (better than 10^{-11}). Hence, Iris recognition is considered a more reliable biometric authentication system [3]. It can have a vast application in various computer vision areas such as Healthcare, Border Security, etc. Iris can be used as an identity, but there is a need to know the features which can identify real and fake ones. Handwrought techniques can find these features.

However, there are classes for iris images, such as live, patterned, coloured, printed, and transparent. The presented work deals with extracting those features for which ML Algorithms will give high accuracy.

The work's most important contribution

- Accuracy evaluation of Iris images of two datasets containing two sensors each.
- Calculated TSBTC for two datasets to evaluate the potential of the TSBTC technique.
- Implemented fusion of TSBTC and Triangle thresholding techniques on various ML

algorithm classifiers and an ensemble of those classifiers.

The paper's overall structure is outlined below. Section 2 presents a literature review of related papers. The proposed method is explained in Section 3. Section 4 presents the experimentation environment, while Section 5 discusses the final results, graphs and observations. Section 6 mentions the outcome in the form of a conclusion.

2. Literature Review

Most studies have tried using several Machine Learning methods with image classifiers for automated detection of the actual or fraudulent iris images. The critical advancements in characterizing the eye's iris may be briefly divided into two categories: those that pull out characteristics to represent picture content and those that create the structure of the deep convolutional neural networks (DCNN) for iris-liveness detection (ILD). The main difference between these approaches is in feature extraction explicitly, image contents (like texture shape and colour information) are explored to generate image signatures for ILD, and these signatures are then used to train machine learning classifiers for ILD. On the contrary, in DCNN, DCNN-based ILD methods extract the iris signatures in an automated sense with the help of convolution and pooling layers of neural networks [4].

In [5], the author studied that creating and training the neural networks for the iris datasets are much more expensive concerning time. Pretrained models are used to train the iris datasets. These models are already trained on ImageNet Dataset and have the weights in a neural network. They used Inception-V3, Xception, and InceptionResNet-V2 as pretrained models to train the MMU iris dataset. These pre-trained models are un-freezed to get retrained on iris datasets using a transfer learning approach with considered hyper-parameters. The approach was mainly an exploration of the transfer-learning ability of pre-rained DCNN models to be used in iris recognition/ classification. The Inception-V3 Model has the highest accuracy, at 96.03%.

In [6], the author researched transfer learning, in which previously trained weights from the ImageNet Model are utilized to shorten the training procedure. In that, they found that pre-trained models learn the features quickly. In the transfer learning approach, the pre-trained DCNN model weights are un-freezed, and models are retrained for the target dataset. The retraining process assures higher training accuracy with adjusted hyper-parameters for the number of epochs. They used Inception v3, VGG-16, EfficientNet, Resnet50 and Densenet121 pre-trained networks, and among them, EfficientNet gave an accuracy of 99.97% for the ND iris 2020 dataset, whereas VGG-16 Model gave 99.75% accuracy.

In [7], the author researched iris presentation attack detection (IPAD). To overcome the low generalization problem of Iris PAD algorithms, they used two head contraction expansion Convolutional Neural Networks (CNN). In this type of CNN-based IPAD, there are two input images: a raw image, i.e., the original image and edge enhanced image. The increased information in the form of edge-enhanced iris images helps in partially overcoming the CNN limitations of the requirement of a large amount of training data. Considering iris images with edge-enhanced versions has shown the performance boosting in the approach [7]. They have used Liv-Det 2017, IIIT D contact lens datasets of iris presentation attack. By this method, the error rate they get is 11.1%.

The study by [8] states that combining TSBTC and GLCM can increase detection accuracy. The TSBTC and GLCM are used to form the feature vectors of iris images. These feature vectors are further employed to train machine learning classifiers (such as decision trees, support vector machines, multi-layer perceptrons, random forests, naive Bayes, and ensembles) for ILD. The experimentation is carried out using datasets alias IIITD Combined spoofing dataset, IIITD Contact Lens, Clarkson LivDet2015, and Clarkson LivDet2013 datasets. The combination approach gave 99.68% accuracy using the random forest, decision tree and MLP ensemble.

Till now, iris recognition technology has been used in several critical application areas like bank ATMs, border surveillance and security, airport authorities for passport-free access to travellers, and citizenship authorization of residents (AADHAR). The faster and more accurate iris recognition will improve the practical acceptance of these systems further. A superior-grade image can easily fool numerous proprietary iris scanners as a replacement for the genuine iris.

3. Method

The Iris recognition systems face significant vulnerabilities, diminishing their reliability for secure data applications. The Thepade’s Sorted Block

Truncation Coding (TSBTC) transforms a two-dimensional image into a one-dimensional array, followed by sorting to enhance security [9]. Subsequently, the array is divided into N segments (where $N \geq 2$), referred to as Ary. The average value of each segment is stored in a CSV file, as illustrated in Figure 1, depicting the TSBTC n-ary representation. The primary principle behind the approach is any image slanted, rotated, or scaled in size may be recognized by detecting characteristics after sorting the image intensities. It makes detection scale and rotation resistant, i.e., it produces the same results even if the provided picture is not of standard size or orientation.

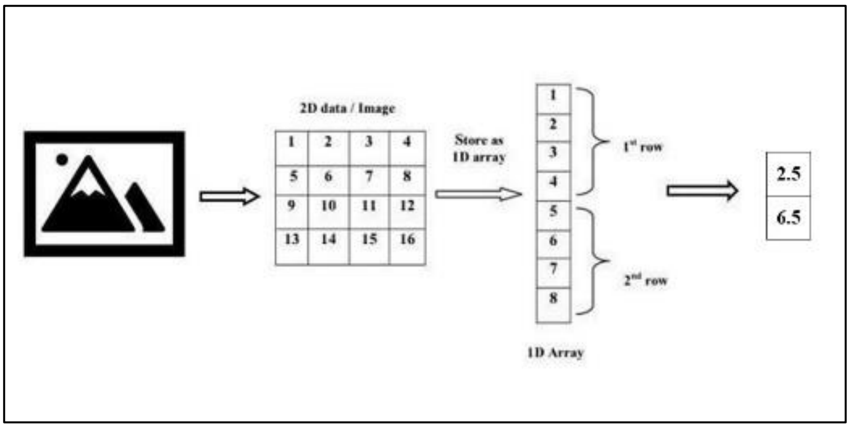

Figure 1. Functioning of TSBTC in which image intensities are sorted and the average is calculated of segments.

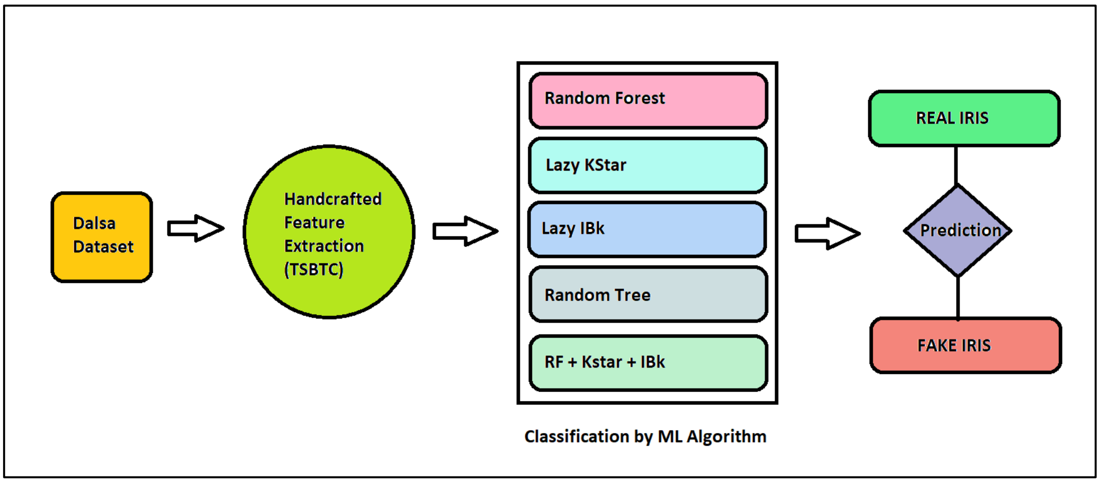

Figure 2. The flow of methodology for detecting legitimate and generated iris images with the help of machine learning methods by providing only handwrought features of images.

After Storing the N segments, i.e., TSBTC Ary, in a CSV file, pass the values through classifiers to predict the accuracy by various methods like ten folds and the percentage method.

Classifiers:

Different machine-learning algorithms from different families have been used to compare the accuracies. Below are the classifiers used while experimenting with various classifiers:

Functions: Multi-layer Perceptron (MLP)

Trees: J48, Random Forest, Random Tree

Bayes: Naïve Bayes

Lazy: IBK, KStar

Another technique used to detect the class of an image is thresholding. Turning a document image into a bi-level document image. Pixel values are assigned corresponding to the provided threshold. Black and white pixels make up a dual collection of image pixels. It separates the background from the foreground feature in an image.

3.1 Triangle Thresholding Method

In the triangle threshold method, images are transformed into a histogram [10]. The plot of pixel intensities and frequency of pixels of an image gives peaks in the histogram by which the method identifies the threshold value to give the binary image. The following steps are used for Triangle thresholding Images are transformed into histograms, as shown in Figure 3.

After plotting the histogram, find the highest peak in the graph and join the line to the end of the histogram. The method finds the maximum perpendicular distance between the graph and the line, as shown in Figure 4.

The pixel intensity point at which the method gets the maximum distance is assigned as the threshold value.

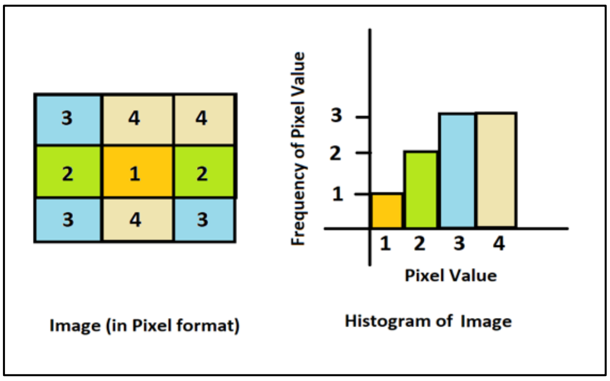

Figure 3. Transformation of image intensities into a histogram of Pixel value vs. frequency of pixel value

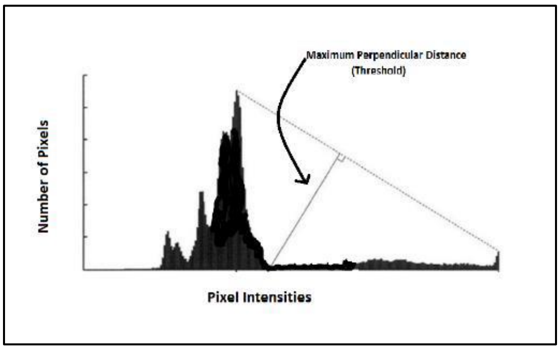

Figure 4. The plotting shows the line between the highest peak and end of the histogram and the maximum perpendicular distance between the histogram and the line.

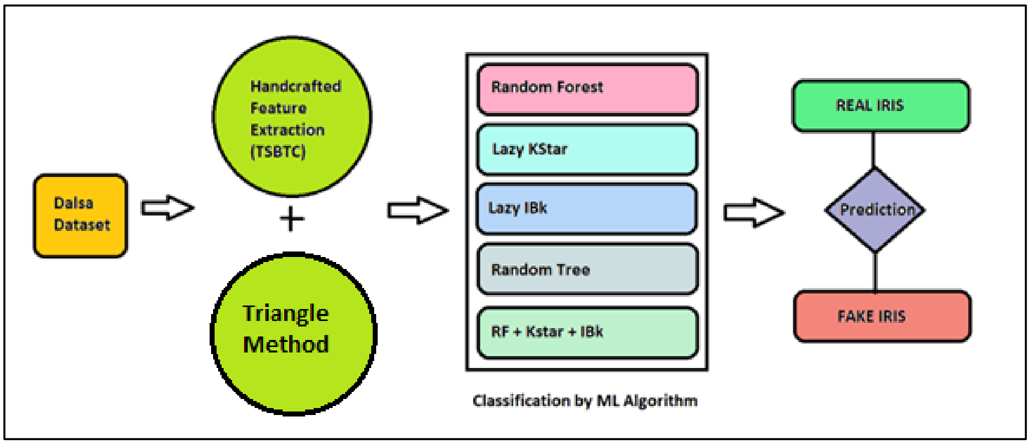

Figure 5. Detection of legitimate and generated iris images with the help of machine learning methods by providing hand wrought features and Triangle thresholding method of images.

Pixel intensities are divided into attributes above and equal to and below the threshold. The averages of all upper and lower pixel intensities are stored in a CSV file. The feature vector from the triangle method is fused with the feature vector of TSBTC N-ary for better classification of an image, as shown in Figure 5 [11].

4. Experimental Setup

The proposed method is validated across two datasets, Clarkson and IIITD, to ensure performance independent of the type of data acquisition sensors. Datasets are referred from [13]. Datasets are as follows:

4.1. Clarkson 2015

Clarkson 2015 is the dataset of two Dalsa and LG sensors containing iris images. It contains files of Live, Patterned, and Printed iris classes of each scanner of resolution 600×400 pixels. Clarkson Dalsa Dataset includes 553 bitmap images of the live class, 314 bitmap images of the pattern class, and 846 bitmap images of the printed class. The pattern and printed class signify the fake iris image. Clarkson LG Dataset includes 258 live class bitmap images, 206 pattern class bitmap images, and 844 printed class images. All these images are in greyscale, which contains the left and right images of the eye.

4.2. IIIT Delhi Dataset

IIIT Dehli dataset is referred from [14]. Vista and Cognet are the sensors used in the IIT Delhi dataset. This dataset has three classes: the iris, Coloured, Normal, and Transparent.

The Vista scanner colour class contains 1150 images, and the Cognet Scanner colour class contains 2207 images. These are all bitmap images which Vista and Cognet Sensors take. All images taken by the sensor are in greyscale of both left and right eyes.

Various classifiers' accuracies are calculated for different values of N for both dataset's sensors. These values are used in feature extraction for global TSBTC and Triangle Method.

For TSBTC, the Python language generates TSBTC Ary values for each image in the dataset known as the feature table. These feature tables are input to various machine learning algorithms. WEKA platform is used to get the accuracy on various ML Algorithms.

5. Results and Discussion

TSBTC Arys incremented to the saturation point of the average of all individual TSBTC Ary. The best-performer classifiers among the classifiers are combined to get more accuracy, and the Ary-wise average for all classifiers is shown to check the best-performed TSBTC Ary among all.

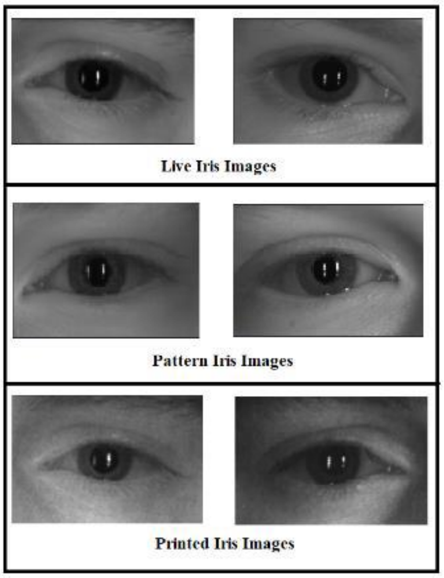

Figure 6. Clarkson Dataset [12]

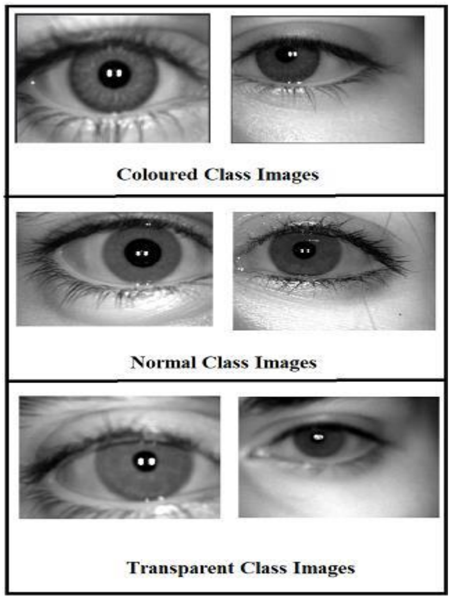

Figure 7. IIIT Delhi Dataset

5.1. TSBTC on Clarkson Dataset (Dalsa Sensor)

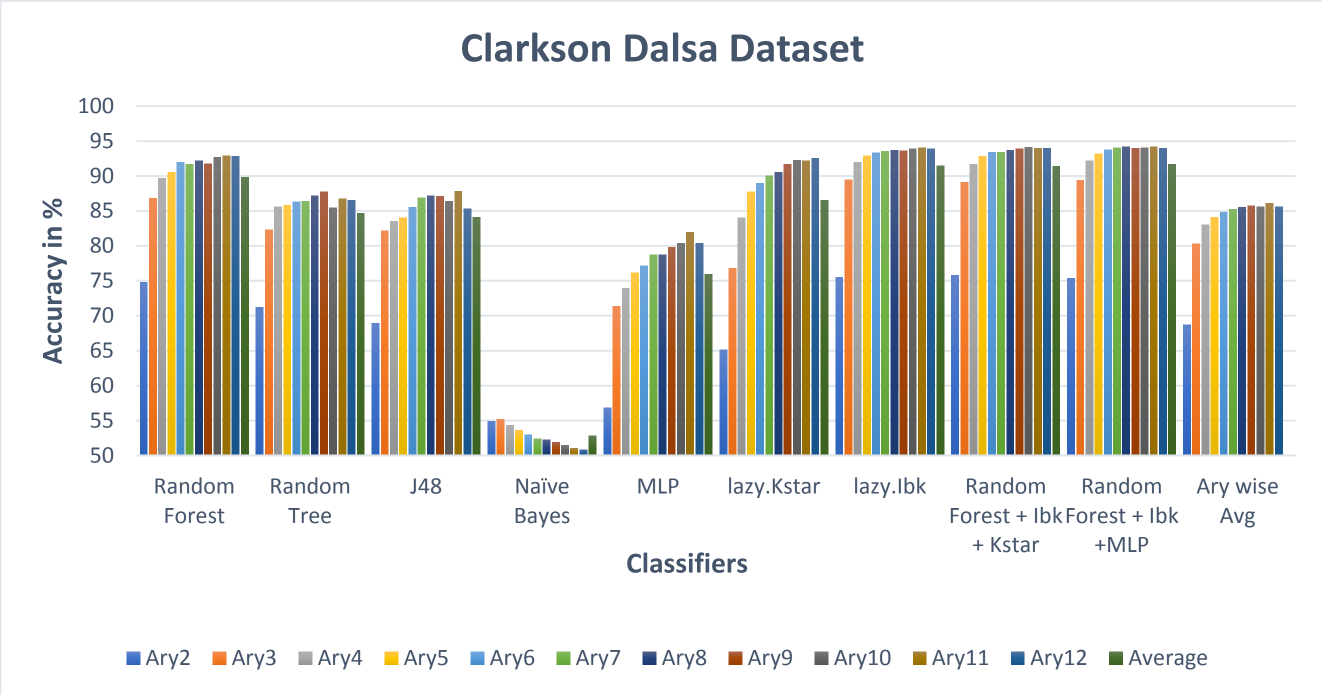

Figure 8. Accuracy-based Performance of Proposed Iris liveness Detection Method with variations of TSBTC for respective ML Algorithm and ensemble experimented on Clarkson Dalsa Dataset.

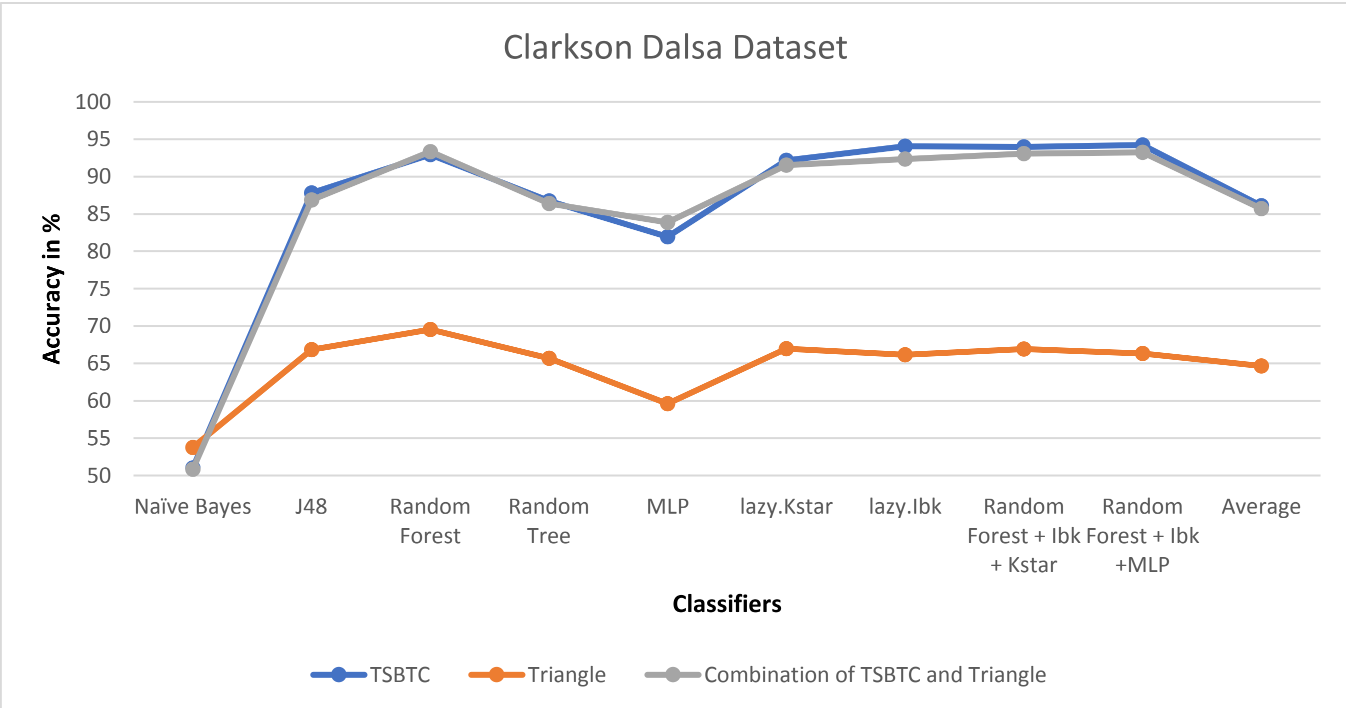

Figure 9. Accuracy-based Performance of Proposed ILD using a combination of Thepade's SBTC and Triangle thresholding features over features of individual methods for respective ML Algorithms and Ensemble experienced on Clarkson Dalsa Dataset.

Figure 8 shows the accuracy of arys for each classifier and ensemble with the average of each. On average, 11Ary is the best among all the TSBTC ary detection. Among all classifier combinations of Random Forest, Ibk, and MLP classifier is performing best. Its accuracy value for 11ary is 94.22%. Followed by a combination of Random Forest, Ibk and Kstar is performing well. From the above graph, it is clear that ensembles are best performing in case of accuracy.

Figure 9 compares the TSBTC-n ary technique alone, the Triangle method and the Combination of TSBTC and Triangle method for the Dalsa Dataset. Accurate detection probability is higher for TSBTC and the Combination of TSBTC and the Triangle method. For some classifiers and ensembles, TSBTC performs best compared to the combination of both.

5.2. TSBTC on Clarkson LG Sensor Dataset

Figure 10. also shows the accuracy in percentage for each classifier of arys. 11ary gives more accuracy for each classifier and combination of classifiers, so 11ary is best among all the arys. The best classifier for detection is the combination of Random Forest, Ibk and MLP, as its accuracy values are higher. Its accuracy value for 11ary is 92.73%.

Figure 11. shows that the Combination of TSBTC and Triangle method gives the best accuracy for most classifiers. On average, TSBTC and a combination of both give the same accuracy for the LG dataset. Random Forest, IBk and MLP classifier gave maximum accuracy for the Combination of TSBTC and Triangle Method, 92.97%.

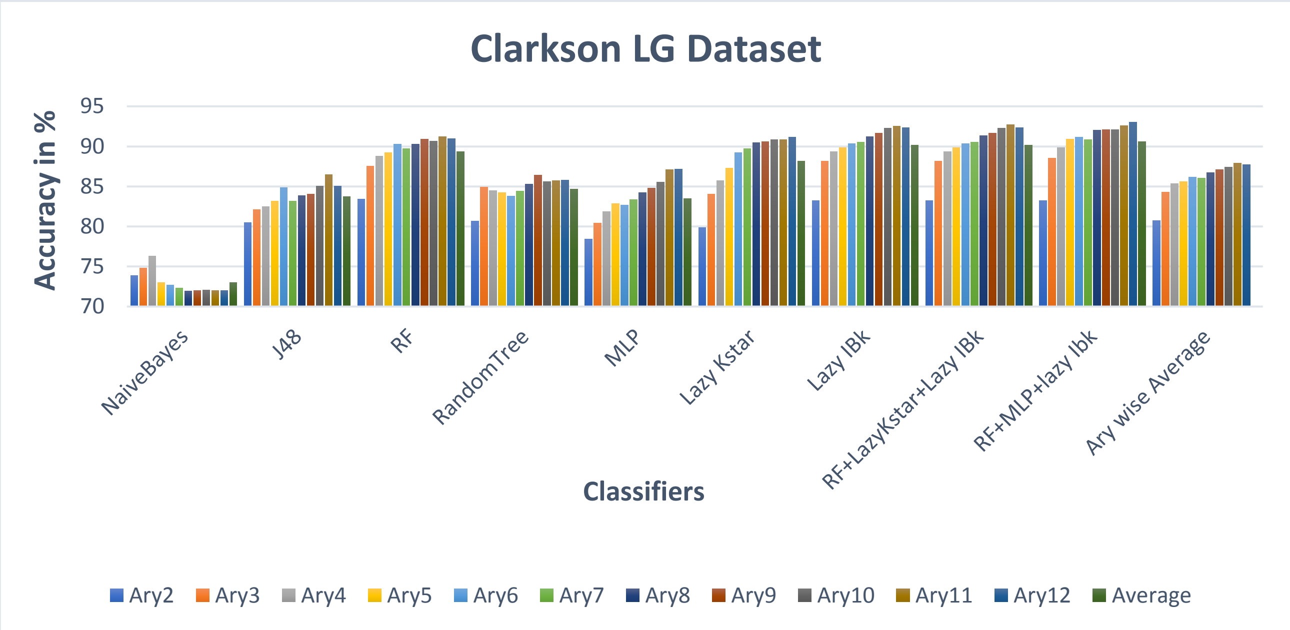

Figure 10. Accuracy-based Performance of Proposed Iris liveness Detection Method with variations of TSBTC for respective ML Algorithm and ensemble experimented on Clarkson LG Dataset.

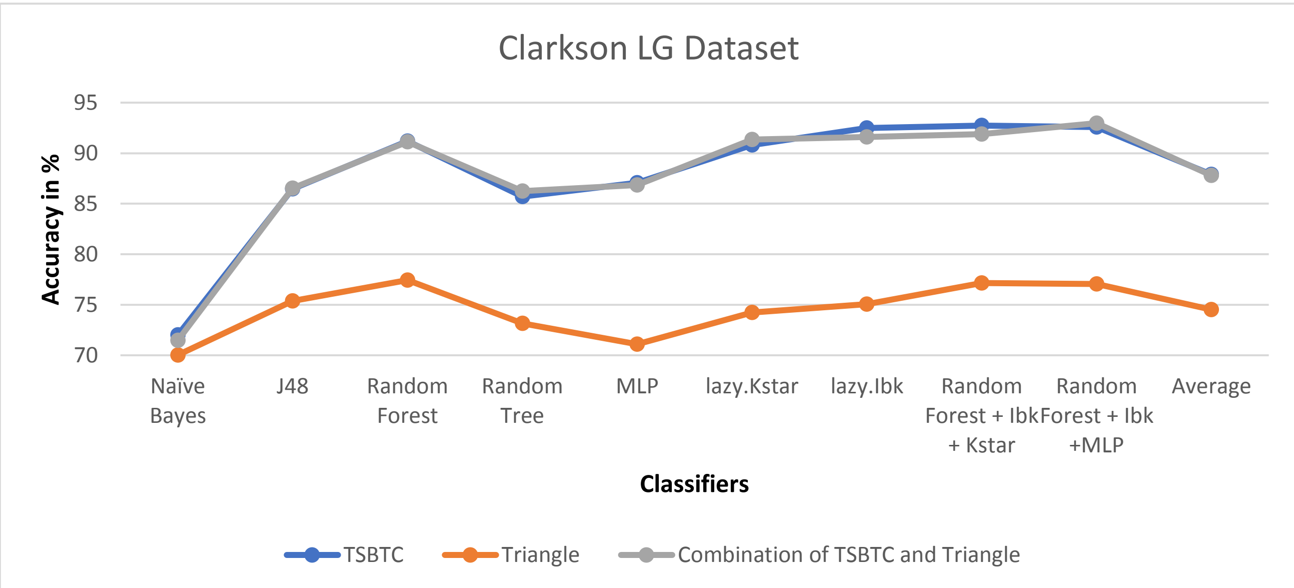

Figure 11. Accuracy-based Performance of Proposed ILD using a combination of Thepade's SBTC and Triangle thresholding features over features of individual methods for respective ML Algorithms and Ensemble experienced on Clarkson LG Dataset.

5.3. TSBTC on IIIT Delhi (Vista Sensor) Dataset

Figure 12 shows the accuracy in percentage in which each classifier contains accuracy of arys. 12th ary averagely performed best among all the arys. The combination of Random Forest, Kstar and IBk gives more accuracy on average than other ensembles and classifiers. Its accuracy value for the 12th ary is 60.63%.

Figure 13 shows that the Combination of TSBTC and Triangle performs best for nearly all the classifiers. On average, the combination performs best compared to TSBTC and Triangle individuals. The accuracy given by the Combination of TSBTC and Triangle for the Kstar classifier is 61.9%.

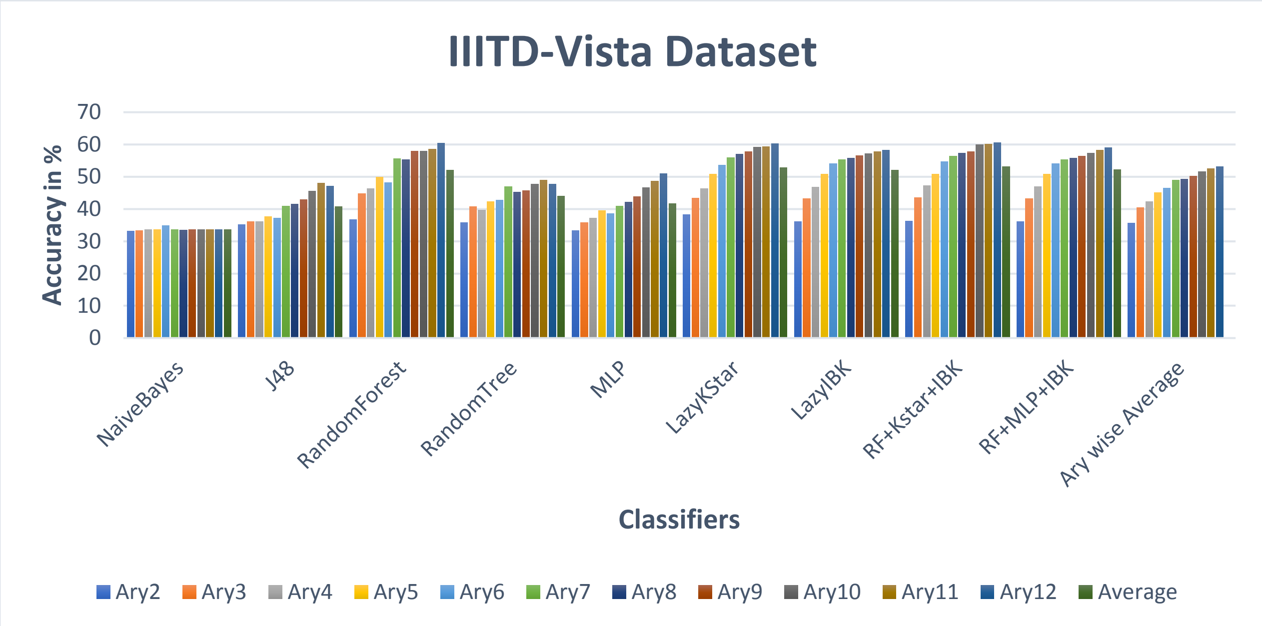

Figure 12. Accuracy-based Performance of Proposed Iris liveness Detection Method with variations of TSBTC for respective ML Algorithm and ensemble experimented on IIITD Vista Dataset.

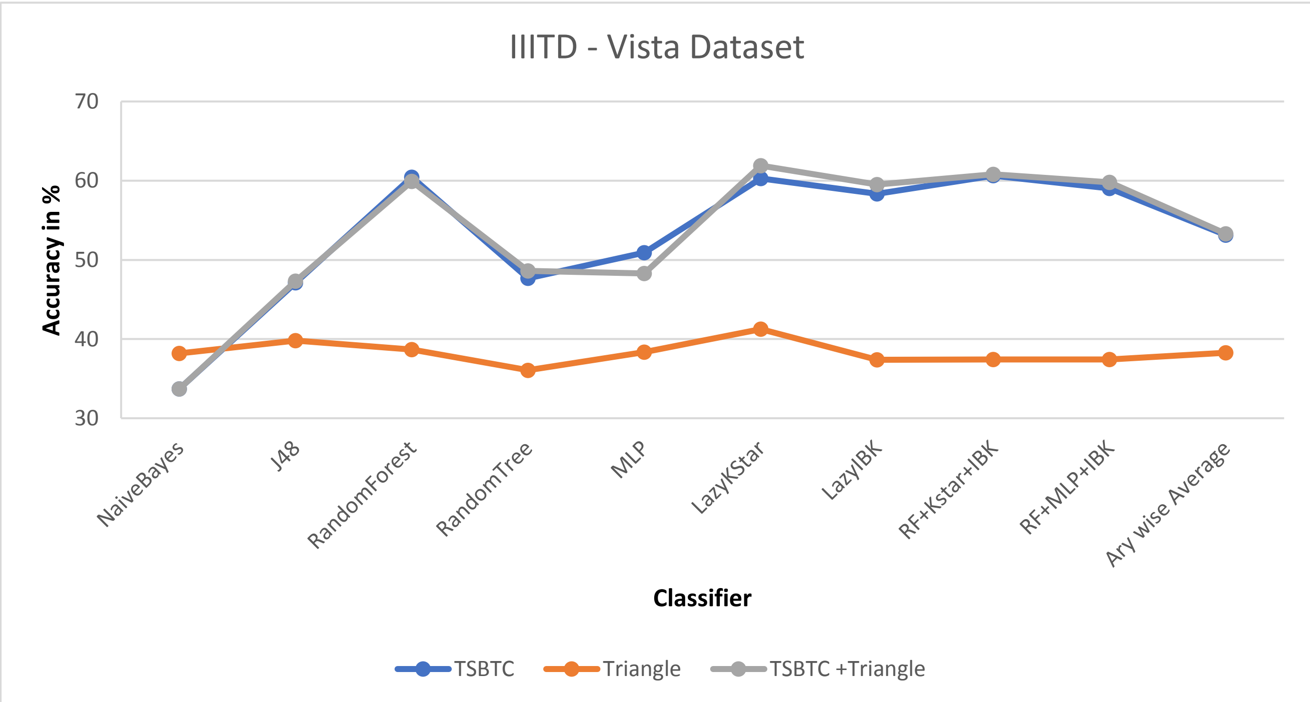

Figure 13. Accuracy-based Performance of Proposed ILD using a combination of Thepade's SBTC and Triangle thresholding features over features of individual methods for respective ML Algorithms and Ensemble experienced on IIITD Vista Dataset.

5.4 TSBTC on IIIT Delhi (Congent Sensor) Dataset:

Figure 14 shows that the Cognet sensor gives more accuracy for the 12th ary averagely performed best among all the arys. The lazy KStar classifier gave maximum accuracy for the Cognet Dataset. The maximum accuracy given by the combination of Random Forest, Lazy KStar and MLP is 64.39% for 12th ary.

Figure 15 shows that the Combination of the TSBTC and Triangle method gives more accuracy than the TSBTC and Triangle individuals. The Maximum accuracy is given by Lazy KStar, which is 67.5%.

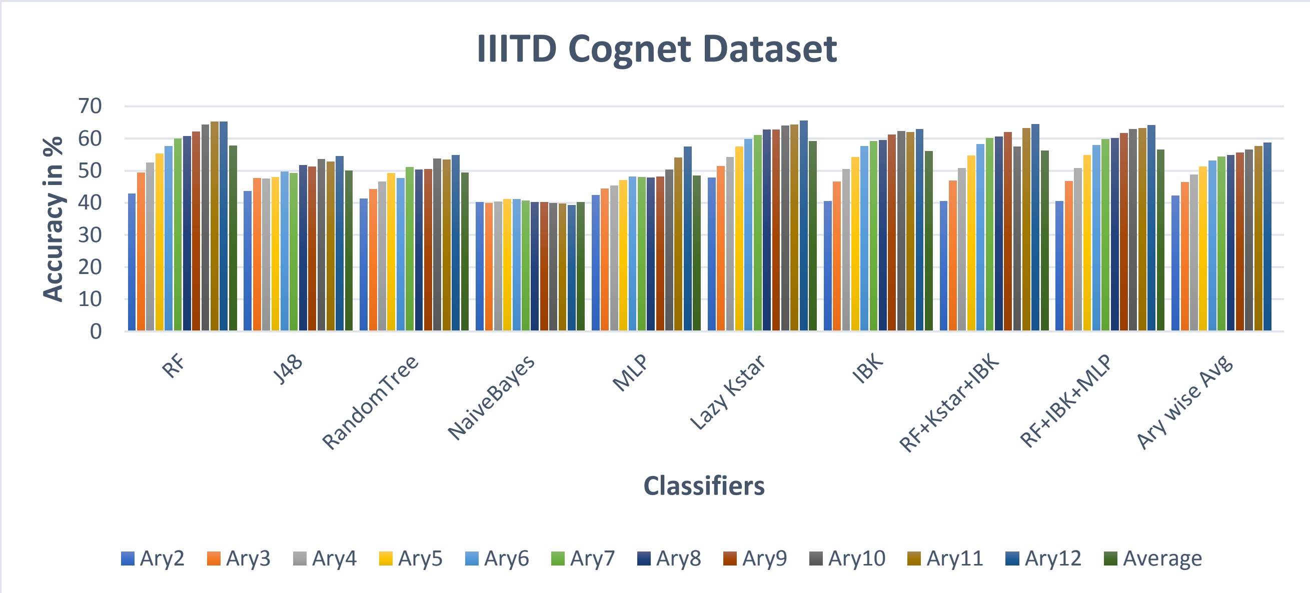

Figure 14. Accuracy-based Performance of Proposed Iris liveness Detection Method with variations of TSBTC for respective ML Algorithm and ensemble experimented on IIITD Cognet Dataset

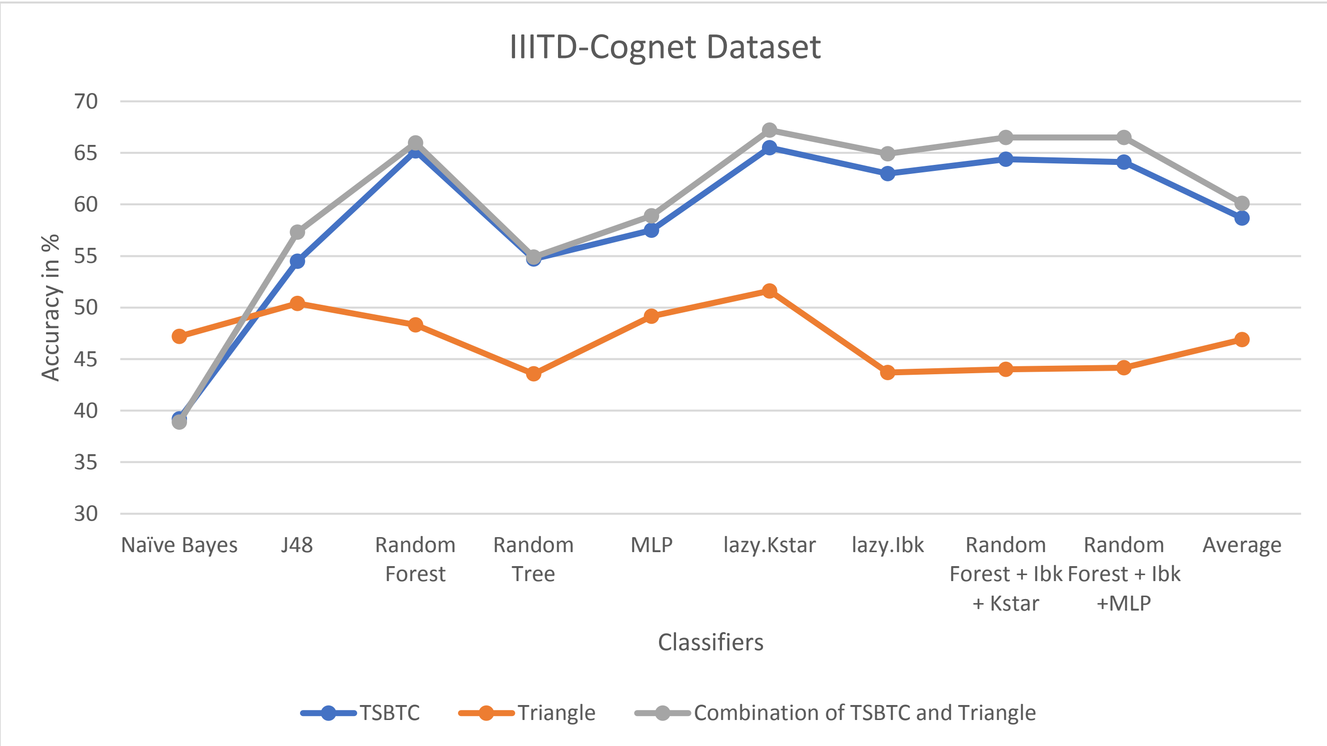

Figure 15. Accuracy-based Performance of Proposed ILD using a combination of Thepade's SBTC and Triangle thresholding features over features of individual methods for respective ML Algorithms and Ensemble experienced on IIITD Cognet Dataset.

Table 1. Comparative analysis of the proposed scheme with related schemes

Reference	Technique	Detection Domain	Advantages	Disadvantages	Results	Datasets Used
M. Abu-Zanona [5]	Feature fusion of GLCM and Deep Learning method	Iris Liveness Detection	Accuracy improved compared to previous methods	Direct feature extraction from images	Accuracy: 97.8%	Clarkson LivDet2013, Clarkson LivDet2015, IIITD Combined Spoofing, IIITD Contact Lens.
Khade, S., Gite, S., Thepade, S. D., Pradhan, B., & Alamri, A. [8]	Fusion of TSBTC global feature and GLCM local feature	Iris Presentation Attack Detection	Fusion gives more accuracy than the alone GLCM and TSBTC methods.	Highly dependent on the quality of data for the detection and can be improved by other thresholding methods	Accuracy for Clarkson: 93.78% and 95.57% IIITD: 78.88%	Clarkson 2013 &2015 IIITD Contact
Khade, S., Gite, S., & Pradhan, B. [8].	Pretrained models used for detection	Iris Liveness Detection	Transfer learning helps to increase the accuracy of iris-liveness detection.	Deep Convolutional Networks are time-consuming and can lead to overfitting of training data.	Accuracy: 99.97%	ND_Iris3D_ 2020, LivDet-Iris Clarkson 2015, IIITD Contact Lens Iris
A. Agarwal, A. Noore, M. Vatsa, & R. Singh [6].	Pretrained Model with the addition of layers	Iris Recognition	Less time is required to train the dataset	Only three pretrained Model used for comparison.	Accuracy: 96.03	MMU Iris Database
Proposed Method	TSBTC global, TSBTC local, Standard local thresholding methods	Iris Liveness Detection	Handcrafted feature generation and combination with binarisation technique	Accuracy can be improved.	Accuracy for Clarkson: 94.22% and 92.97% IIITD: 65.8%	Clarkson 2015 IIITD Contact lens

6. Conclusion

The above research provides an improved approach to classify a spoofed and standard image with the help of a machine learning algorithm. The triangle method, a binarisation technique, is fused with the global and local thresholding TSBTC method. This handwrought technique has given accuracy more or equal to the individual TSBTC method and most handwrought techniques. TSBTC method plays a significant role in the detection of images. In TSBTC, amidst possibilities starting from TSBTC 2Ary till TSBTC 12Ary, which variation was better suiting for ILD was challenging to know. This is overcome by exploring all possibilities.

How to use the triangle thresholding used for image binarisation for image signature generation was the difficulty encountered, which was overcome in the proposed method.

Currently, iris recognition technology has demonstrated its application in pivotal sectors such as bank ATMs, border security, airport controls for streamlined traveller access, and citizen verification (like AADHAR). However, to realize its full potential in the real world, advancing the speed and accuracy of iris recognition is crucial. The improved method has adaptability across various conditions, such as varying image size and rotating the image, which increases its real-world utility.

TSBTC extracts image features by considering global information (all pixel values considered).

Triangle thresholding generates image features using local information consideration (applied individually on smaller pixel windows).

The proposed method combines the global and local features giving better ILD capability, proving the worth of the work.

Features collected from the TSBTC and Triangle method are fed to the machine learning algorithms. Random Forest and Lazy IBk were more accurate than all other classifiers. But the Ensembles, i.e., the combination of classifiers such as Random Forest, Lazy IBk, MLP combination and Random Forest, Lazy KStar and Lazy IBk combination, gives more accuracy for the fused features of TSBTC and Triangle method. Naive Bayes is a relatively simple algorithm, making a strong assumption of independence between the features so that it would be biased and less flexible. Naive Bayes has been amongst the earliest models used for data generation, though not for data as complex as images. All naive Bayes classifiers assume that the value of a particular feature is independent of the value of any other feature. For the Clarkson Dalsa dataset, only the fused feature gave comparatively less accuracy than the individual handwrought technique. Still, other sensors such as LG, IIIT Delhi Vista, and Cognet sensor images gave better accuracy than the individual handwrought technique features. As both the datasets Clarkson and IIITD are perfectly balanced (have an equal number of samples for each forged and real iris), the accuracy is apt as performance metrics.

Deciding the window size in triangle thresholding would be interesting future work. Also fusion of global TSBTC features with other local image binarization-based features will be an important future exploration direction.

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Authors Contribution Statement

Sudeep Thepade- Methodology, Data collection, Conceptualisation, Supervision, Validation, review; Lomesh Wagh- Analysis, Implementation, Accuracy Assesment, Writing—review & editing. All authors read and approved the final manuscript.

Has this article screened for similarity?

Yes

Conflict of Interest

The Authors have no conflicts of interest on this article to declare.

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