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DEVELOPMENT OF ENHANCED IRIS AUTHENTICATION BASED BIOMETRIC SYSTEM

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ABSTRACT

The use of biometric authentication, which uses a person's fingerprint, face, iris, handwriting, or other distinctive physical or behavioural characteristics to identify them, is becoming more and more common. When using traditional authentication methods, password protection and memory loss become challenges. This is where biometric authentication steps in to help. The Iris provides the highest degree of uniqueness, universality, precision, and reliability of all the biometrics now in use. The proposed system aims to enhance the security and accuracy of biometric identification through the integration of advanced image processing techniques. The methodology consists of multiple steps: pre-processing (histogram equalization), segmentation (Canny edge and Hough transform), normalizing (Daugman's rubber sheet model), feature extraction (Gabor filter), and matching (Hamming Distance). While segmentation makes it easier to isolate pertinent iris information, histogram equalization attempts to improve image contrast. Normalization guarantees that features are represented consistently, and the process of feature extraction that follows, extracts discriminative data that is essential for precise authentication. In order to compare retrieved features and assess how similar Genuine and Imposter iris patterns are, the matching stage uses a strong algorithm. The average performance metrics obtained reveal promising results, with Recall, Specificity, FAR (False Acceptance Rate), FRR (False Rejection Rate), Precision, F-measure, and Accuracy are reported as 85.20%, 58.87%, 38.11%, 21.97%, 63.33%, 64.80%, and 99.57%, respectively. These results highlight how well the suggested method works to achieve high accuracy and reliability levels, with a focus on how well it can reduce the rates of false acceptance and rejection. With potential applications in a variety of domains, including access control, identity verification, and secure transaction authentication, the work advances safe biometric systems.

Keywords: Iris, Authentication, Normalization, Feature Extraction, Accuracy, Segmentation, Performance Evaluation Metrics, MMU Iris Dataset

INTRODUCTION

The word Biometric was derived from the Greek language; where bio means "life", and the word metric means "to measure". Biometric recognition refers to an automatic recognition of a person based on one or more physical or behavioral feature. It is often required to identify a person, the identification can be carried out by an authorized person or by a machine. In the latter case the machine uses one or more physical characteristic (such as a fingerprint, iris pattern, or face) or behavioural patterns (such as hand-writing, voice, or key-stroke pattern) to identify the person. A biometric system provides automatic recognition of an individual based on some sort of unique feature or characteristic possessed by the individual (Sathish *et al.,* 2012).

Biometric systems have been developed based on fingerprints, facial features, voice, hand geometry, Iris, handwriting, retina etc. Most of these physical or behavioral features have some shortcomings e.g the fingerprint can be blurred or lost through chemical actions, diseases such as leprosy, accidents e.t.c. The face can be blurred or disfigured due to accidents, behavioral pattern on the other hand can be easy altered by emotions, intoxicants or neural sickness. The Iris from the human eye as a means of identification was presented in this dissertation. Oyeniran *et al*. (2019) proposed a multi-algorithmic technique for personal recognition of iris using multiple classifiers approach. They applied Hough Circular Transform for the localization and segmentation techniques in order to isolate an iris from the whole eye image and for noise detection. The normalization procedure was carried out using Daugman Rubber Sheet Model, while the feature extraction was done using Continuous Wavelet Transform. At the classification stage, Hamming Distance, Nearest Neighbour and Euclidean Distance Classifier was adopted. The method has an accuracy of 70%, FAR of 0.00% and FRR of 0.03%. Carothers *et al*., (2015) designed an efficient parallel circuit for unwarping the iris in real time using FPGA. The architecture parallelized the algorithm of unwarp iris based on Bresenham Circle Algorithm (BCA) which supports the parallel architecture. A neural network and discriminant analysis of machine learning method for iris recognition using MATLAB 2016a was implemented in Joshua *et al*., (2020). The proposed method gives better recognition rate than SVM technique with less computational complexity. Neural network and discriminant methods are used for matching and finding recognition accuracy. Thus, the accuracy obtained from neural network is 94.44%, whereas from discriminant analysis the accuracy obtained is 99.99%. The NN algorithm requires a lot of computational time and memory that leads to computational complexity and limits the performance of the system.

An enhanced iris feature extraction using continuous wavelet transform was proposed in Gowroju & Kumar, (2012). The method considerably reduces the computation time and improves the accuracy compared with Gabor filter, Fourier transform and other wavelet transforms. They obtained 0.8% FAR, 1.4% FRR and 97.8% performance recognition accuracy when implemented on CASIA database. The CWT produces a lot of redundant information as it generates coefficients for every possible scale and frequency, this limit the discriminative power of the iris features.

However, Sridev & Shobana, (2022) presents a robust pupil segmentation method using the modified UNet CNN model to perform segmentation. They used MMU (Multi Media University) Iris database, the performance of the system achieved an accuracy of 91.7%. An iris recognition system using MMU dataset was also presented in Rahmatullah *et al*., (2022), they used Camus and Wildes segmentation model after pre-processing was done to eliminate undesirable noise from the images, then proceed to normalization followed by the matching algorithm. The outcome of this study indicates that using the Wildes Segmentation technique on MMU Database an accuracy of 76% was obtained.

Hybrid technique combining edge detection and segmentation, in addition to the convolutional neural network (CNN) and Hamming Distance (HD), for extracting features and classification was studied in Rashad *et al*., (2011). The model was applied to different datasets, which are CASIA-Iris-Interval V4, IITD, and MMU. The model showed a performance accuracies of 94.88% based on applying HD on CASIA, 96.56% based on applying CNN on IITD, and 98.01% based on applying CNN on MMU. The CNN algorithm classifier requires a lot of computational time and memory which leads to computational complexity and can affect the performance of the system.

Furthermore, Ives *et al*., (2011) proposed a statistical pattern approach called local binary pattern (LBP) along with histogram properties to extract the iris texture information to design a feature vector. This feature is fed as an input to a neural network based classifier called combined LVQ. The LVQ classifier requires a lot of processing time and memory especially for high-resolution images or large search spaces, this can limit the efficiency and speed of the system. Ngo *et al*., (2014) studied the locational region area that most of the iris features lies in the eye. They used the RED algorithm for extraction iris features. The authors of this research divided the iris into sectors and try to compare these sectors with each other to find where the most of information (features) lies in the iris. The Red algorithm has a limited bandwidth and cannot capture details of iris texture at very high or low frequencies, therefore it limits the power of the iris features and affect the accuracy. Verma, (2012) conducted a hardware design to make a real time segmentation process. The author of this research designed and implemented parallelized algorithm for segmentation process using FPGA. The design made for canny edge detection and circle Hough transform. The author build high-speed iris segmentation system, which can works in real time, show the benefit of designing and implementing the segmentation process using FPGA. Whereas, the Field Programmable Gate Array require a programming complexity which is challenging and time consuming.

Song & Zunliang, (2014) adopted a new iris recognition method based on a robust iris segmentation approach for improving iris recognition performance. They used robust iris segmentation approach on power-low transformation to increase the accuracy of the pupil region, it is significantly reduces the people limbic boundary search region for increasing accuracy and efficiency in detection. The algorithms can be affected by noise in the image which can limit the accuracy of the iris boundary. Abikoye *et al.*, (2014) presented a method based on sparse error correction model, since the noise factors like eyelid and eyelash occlusion and specular and pupil reflections are mainly spatially localized. In this approach training sets of all iris images are considered as a dictionary used for the purpose of classification of simple test sample and finally converted to a huge size dictionary.

However, Siswanto *et al*., (2014) conducted a method of classification of handwritten signature based on neural networks, and FPGA implementation. The designed architecture is described using Very High Speed Integrated Circuits Hardware Description Language (VHDL). The training part of the neural network has been done by using MATLAB program; the hardware implementations was developed and tested on an Altera DE2-70 FPGA. Abidin *et al*., (2013) adopted a novel algorithm for Circle Hough Transforms using FPGA. The design proposed by the authors help to reduce the memory required space to 93% comparing to other direct systems for circle Hough transforms. The authors designed an algorithm that reduces the required amount of embedded memory bits without losing the accuracy of segmentation.

MATERIALS AND METHODS

The step by step design of the iris authentication system; starting with the process of Image Acquisition followed by Iris segmentation is described in Fig.1 After the segmentation process, normalization algorithm follows and feature extraction then finally the matching algorithm.

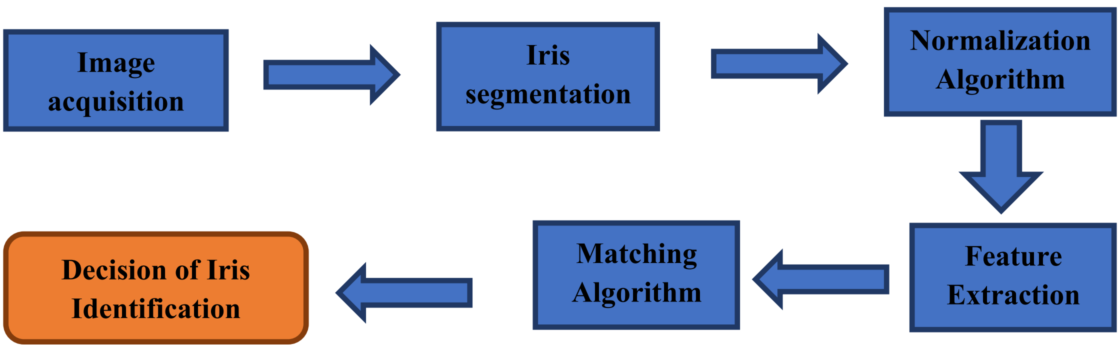

Figure 1: Block diagram of the system

Image Acquisition

The first step of the system framework is image acquisition and pre-processing, which is considered to be the most critical step in the system, since all subsequent stages depends on the image quality and successful pre-processing. The images were obtained from an online database of eye images known as the MMU dataset. The Multimedia University eye data set is a collection of eye images that can be used for biometric research and evaluation, it contains 450 eye images. Histogram equalization is a technique used to improve the contrast of an image (Sathish *et al*, 2012) by adjusting the intensity distribution of the pixels. The histogram represents the distribution of pixel intensities in the image represented by equation 1.

$$pdf(x) = pdf(r_k) = \frac{total\ pixels\ with\ intensity\ r_k}{total\ pixels\ I\ image\ x} \quad (1)$$

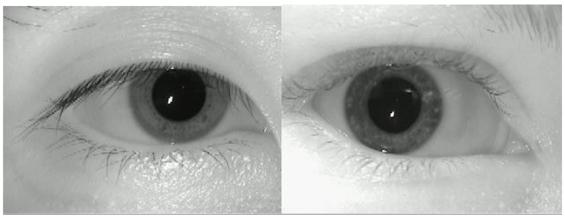

Figure 2: Sample Images of MMU Dataset

Iris Segmentation

Segmentation is a process in which the iris area will be extracted from the captured image. The canny edge detection is the first task in the segmentation algorithm. It was found that by applying proper edge detection techniques iris recognition system could achieve higher accuracy rates (Shaaban & Ibrahim, 2013). The steps involved in carrying out the canny edge detection process include; Gaussian smoothing process, Sobel gradient calculation process, Double thresholding process and hysteresis process.

Gaussian smoothing process

The Gaussian smoothing process uses the Gaussian filter to reduce noise in the image. The Gaussian filter is a kernel that is convolved with the image, it is a low-pass filter that removes high-frequency components from the image while retaining the low-frequency components. This helps to smooth out the image and remove any small variations in intensity that are not part of the edges. In this work a 5x5 kernel was used which offers a good compromise between the quality of smoothing and computational efficiency. The Gaussian kernel is a 2D matrix that represents the Gaussian function given in equation 2 below;

$$K(x,y) = \frac{1}{2\pi\sigma^2} \cdot e^{-\left(\frac{x^2+y^2}{2\sigma^2}\right)} \quad (2)$$

Where:

(x) and (y) are the pixel coordinates relative to the centre of the kernel.

σ (sigma) is the standard deviation of the Gaussian distribution.

Sobel gradient calculation

Sobel gradient calculation technique is used to compute the gradient magnitude and direction at each pixel in an image. It operates using two 3x3 convolution kernels, one for detecting the gradient in x-axis and the other for detecting the gradient in y-axis as shown in equation 3.

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (3)$$

Double thresholding and Hysteresis

Double thresholding process and hysteresis were used to identify and link edge pixels based on the magnitude of gradient values and to eliminate the edge pixels that comes from noise and colour variation.

Hough Transform

The Hough Transform algorithm is used to search for the best circle that represents the iris. The Circular Hough Transform (CHT) is a variation of the Hough Transform used for detecting parameters of the iris's circular or elliptical shape in images (Jan & Usman, 2014) (Rai & Amanika, 2014) (Winston & Themanth, 2020). The Circular Hough transform model (CHT) is then used in order to estimate the iris radius and centre and then the non-iris regions are removed. To detect circles using the Circular Hough Transform equation 4 was used.

$$A(c_x, c_y, r) = \sum_{i=1}^{N} \delta(d(x_i, y_i, c_x, c_y) - r) \quad (4)$$

Normalization

The Normalization algorithm converts the segmented iris from polar coordinates to a rectangular coordinate form, allowing for standardized feature extraction. This is done to mitigate variations in iris images caused by factors like differences in pupil dilation, lighting conditions, camera angle, and other environmental factors. Daugman's Rubber Sheet Model algorithm was used, it is a simplified algorithm for the conversion of a segmented iris from polar coordinates to rectangular coordinates(Sathish *et al*, 2012) using equation 5.

$$x(r,\theta) = (1-r)\, x_p(\theta) + r\, x_s(\theta)$$
$$y(r,\theta) = (1-r)\, y_p(\theta) + r\, y_s(\theta) \quad (5)$$

Where;

Xp(θ), yp(θ), xs(θ), ys(θ) are the discrete coordinates near the pupillary boundary at a given angle θ [0, 2π] and r is the normalized radius in the interval [0, 1].

Feature Extraction

Gabor filter algorithm was used as the feature extraction algorithm. Gabor filters are known for their ability to capture fine-grained texture information in iris images, they are particularly effective at encoding iris texture patterns and are robust to variations in lighting and noise. Gabor filters are defined by equation 6;

$$G(x,y) = e^{-\left(\frac{x'^2+Y^2 y'^2}{2\sigma^2}\right)\cdot cos\left(2\pi\frac{x'}{\lambda}+\phi\right)} \quad (6)$$

Where:

(x) and (y) are spatial coordinates.

x' = xcos(Θ) + ysin(Θ) and y' = -xsin(Θ) + ycos(Θ) represent the coordinates in the direction (Θ).

(σ) controls the standard deviation of the Gaussian envelope.

(λ) represents the wavelength of the sinusoidal component.

(γ) is the spatial aspect ratio (elongation of the filter).

(π) is the phase offset.

Matching Algorithm

The Hamming Distance (HD) is a metric used to measure the similarity or dissimilarity between two binary strings of equal length, it measures the closeness of the iris templates between each other. A smaller Hamming distance indicates a higher degree of similarity between the two templates, while a larger distance indicates greater dissimilarity. This algorithm uses a threshold value of 0.34.

The Hamming distance (HD) between two Boolean vectors defined by equation 7;

$$HD = \frac{1}{N} \sum_{j-1}^{N} C_A(j) \oplus C_B(j) \quad (7)$$

Performance Evaluation Metrics

Biometrics systems performance are generally evaluated using accuracy, recall, precision, specificity, and f1-score. The following evaluation parameters are used to calculate the effective performance of the system:

True Positive (TP)
This is the case where the system correctly predicted a positive outcome, in this report identifying a genuine match.

True Negative (TN)
This is the case where the system correctly predicted a negative outcome, i.e correctly rejecting an imposter as a non-match.

False Positives (FP)
False Positive is the case where the system incorrectly predicted a positive outcome, i.e wrongly accepting an imposter as a match.

False Negatives (FN)
False Negative is the case where the system incorrectly predicted a negative outcome, i.e the systems fails to recognize a genuine match and incorrectly rejects it.

Precision
Precision is an important performance evaluating parameter, it is used to assess the system's ability to make positive prediction correctly. High precision would mean that the system makes fewer false positive errors. It is mathematical given by equation 8 ;

$$\text{Precision} = \frac{TP}{TP+FP} \quad (8)$$

Recall
A recall also referred to True Positive Rate (TPR) measures how good the system correctly identifies a genuine match. A high recall indicates that the system is good at authentication and a low indicates a high rate of rejections or missed matches. TPR is given by equation 9;

$$\text{Recall} = \text{TPR} = \frac{TP}{TP+FN} \quad (9)$$

Specificity
Specificity also referred to as TNR measures the proportion of non-matching cases that the system correctly identifies as imposters out of the total number of non-matches. A high TNR indicates that the system is good at rejecting non-matching irises. It is mathematically expressed as equation 10.

$$\text{True Negative Rate} = \frac{TN}{TN+FP} \quad (10)$$

False acceptance ratio
False acceptance ratio (FAR) is the rate at which the system incorrectly accepts an imposter as a genuine match. A lower FAR indicates the system is likely to reduce unauthorized authentication. It is mathematically expressed as given in equation 11;

$$\text{False Acceptance Ratio} = \frac{FP}{FP+TN} \quad (11)$$

False rejection ratio
False Rejection Ratio (FRR) is a measure of the rate at which the system incorrectly rejects a genuine iris as a non-match. A lower FRR indicates that the system is more reliable in correctly identifying genuine users. The false acceptance ratio is mathematically expressed as in equation 12:

$$\text{False Rejection Ratio} = \frac{FN}{FN+TP} \quad (12)$$

F-Measure
F-measure is a statistical technique for examining the accuracy of a system by considering both the precision and recall of the system. A higher F-Measure indicates that a system can correctly identify genuine matches while maintaining a balance between precision and recall. The F-measure is mathematically expressed by equation 13;

$$\text{F-Measure} = 2\left(\frac{Precision \times Rcall}{precision+Rcall}\right) \quad (13)$$

RESULTS AND DISCUSSION
The evaluation of the results was based on performance metrics. The system was tested using MATLAB environment and all parameters were obtained from the system outcome. An average value in percentage was taken from a sample of ten different images, with each parameter showing the performance of the authentication. All the reported performance parameters are within the range of 0% to 100%, for evaluation. Fig. 3 presents the system average performance parameters given as; 85.20%, 58.87%, 38.11%, 21.97%, 63.33%, 64.80%, and 99.57% for Recall, Specificity, FAR, FRR, Precision, F-measure and Accuracy.

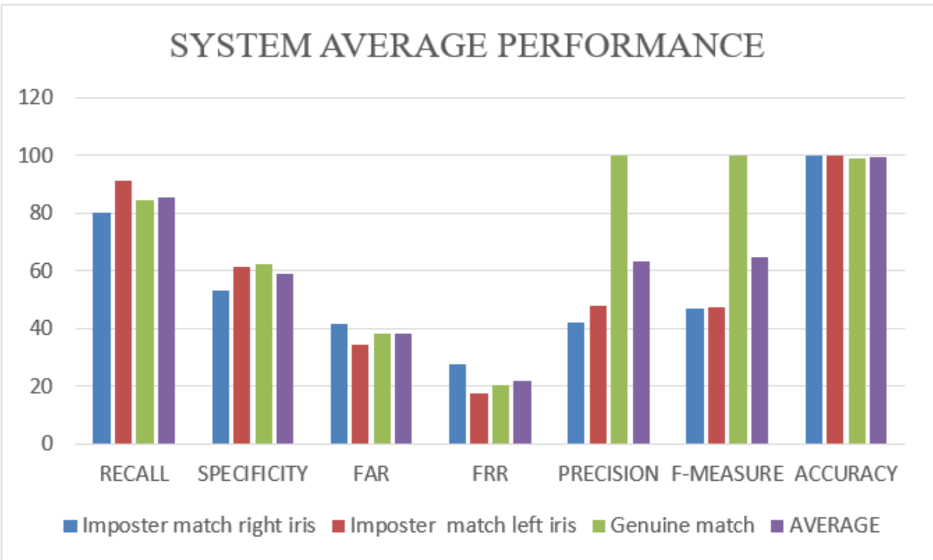

Figure 3: System Average Performance

From these results, it can be deduced that;

i. The system has a high Recall/True Positive Rate of 85.20% showing that it is good at authentication.
ii. The system has an average Specificity/True Negative Rate of 58.87% showing that it is good at rejecting a non-match.
iii. The system has a low False Acceptance Rate of 38.11% indicating that it is likely to reduce wrong acceptance of an imposter as genuine iris.
iv. The system has also a low False Rejection Rate of 21.97% which indicates that it is reliable in correctly identifying a genuine match.
v. The system has a Precision of 63.33% which indicates a low false positives prediction and minimizing the chance of incorrect authentication.
vi. The system has an F-measure of 64.80% indicating that the system achieves a good balance between accurately predicting true positives and capturing all relevant instances, leading to a robust overall performance.
vii. The system has an Accuracy of 99.57% indicating that the system performs well in distinguishing different iris patterns there by authenticating a genuine and imposter match leading to a reliable system.

Result Comparison

The proposed study demonstrates a significant advancement in comparison to related studies in terms of accuracy. A comprehensive analysis of the results obtained in this study and those reported in Rahmatullah *et al.*, (2022), Gowroju & Kumar, (2021), Winston & Themanth, (2020) and Sridev & Shobana, (2022) provides valuable insights into the effectiveness of the proposed system.

In the study by Rahmatullah *et al.*, (2022), the reported accuracy of 76% suggests a notable improvement in the proposed system, which achieved an accuracy of 99.57%. This substantial increase underscores the superior performance and reliability of the developed system.

Similarly, Gowroju & Kumar, (2021) reported an accuracy of 94.96%, which, while impressive, is surpassed by the proposed system's accuracy of 99.57%. This outcome reflects the enhanced capabilities of the proposed system in achieving a higher level of accuracy in iris authentication. Winston & Themanth, (2020) reported an accuracy of 86%, and Sridev & Shobana, (2022) reported an accuracy of 91.7%. In both cases, the proposed system outperforms these results significantly with its accuracy of 99.57%. This indicates a substantial improvement in the proposed system's ability to accurately authenticate individuals.

Fig. 4 shows the True Positive Rate and True Negative Rate results comparison of Sridev & Shobana, (2022) and the proposed study.

Also, Fig. 5 shows the Accuracy comparison of the proposed work to the recent related works.

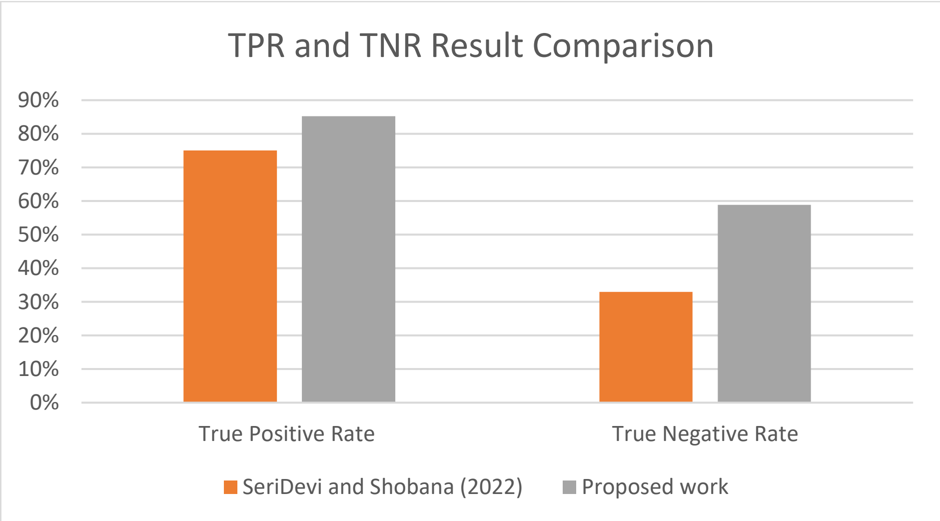

Figure 4: TPR and TNR Result Comparison

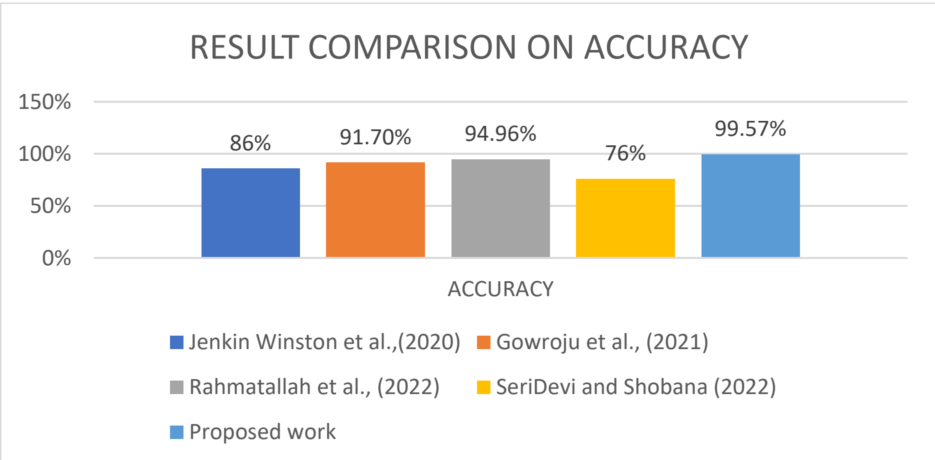

Figure 5: Result Comparison on Accuracy

CONCLUSION

The Iris authentication system is one of the most accurate biometric method used today, features inside the iris makes it unique amongst all individuals. The average results, with a focus on Recall (85.20%), Specificity (58.87%), False Acceptance Rate (FAR, 38.11%), False Rejection Rate (FRR, 21.97%), Precision (63.33%), F-measure (64.80%), and Accuracy (99.57%), serve as a measure to the system's efficiency. The reported performance metrics demonstrate the system's effectiveness in achieving high accuracy rates, emphasizing its capability to minimize both false acceptance and false rejection. In general, the proposed system shows a competitive performance compared to some recently published related work on Iris recognition or authentication using the MMU dataset. It can be concluded that this work make a remarkable contribution to the biometric recognition space. This study contributes valuable insights to the field of iris authentication, by utilizing techniques that enhance the performance of an iris authentication system with less computational expenses. It paves the way for further advancements in secure and accurate biometric identification systems.

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