International Scientific Journal of Engineering and Management (ISJEM)
Volume: 04 Issue: 04 | April – 2025
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata
ISSN: 2583-6129
DOI: 10.55041/ISJEM02981

Iris Recognition Systems: A Comprehensive Review

Tejas Tawrej[1], Karan Thapa[2], Khushal Hedaoo[3], Krishna Patil[4], Prof. Dipali Chhatrikar[5]

[1]Department of Electronics and Telecommunication Engineering, JSPM Rajarshi Shahu College Of Engineering
[2]Department of Electronics and Telecommunication Engineering, JSPM Rajarshi Shahu College Of Engineering
[3]Department of Electronics and Telecommunication Engineering, JSPM Rajarshi Shahu College Of Engineering
[4]Department of Electronics and Telecommunication Engineering, JSPM Rajarshi Shahu College Of Engineering
[5]Department of Electronics and Telecommunication Engineering, JSPM Rajarshi Shahu College Of Engineering

---***---

Abstract - Iris recognition systems have emerged as a leading solution for secure and reliable biometric identification, leveraging the intricate and unique patterns of the human iris. This review examines four key algorithms—Hough Transform, Daugman's Rubber Sheet Model, SIFT, and SURF—used in iris recognition. We discuss their applications across sectors such as security, access control, and identity verification. The paper highlights the challenges, advantages, and future directions of these technologies, offering a detailed analysis of their accuracy, efficiency, and robustness.

***Key Words*:** Iris recognition, Biometric authentication, Iris scanning, Image processing, Database security

1. INTRODUCTION

In today's increasingly digital world, where online transactions have become important and necessary, the need for secure and user-friendly payment methods has never been more pressing. Traditional authentication approaches, such as passwords and PINs, often fall short in providing the robust security and seamless experiences that today's discerning consumers demand. As a response to these challenges, biometric authentication technologies have emerged as promising alternatives, leveraging the unique physiological or behavioural characteristics of individuals for identity verification.

Among the biometric modalities, iris recognition technology stands out for its unparalleled accuracy and reliability. The iris, with its intricate patterns and stable characteristics, serves as a highly distinctive biometric identifier. Its complex structure, comprising cryptographically unique features, makes it exceedingly difficult to replicate or forge, thus offering a superior level of security in authentication processes.

A. Illustrating Iris Structure: Highlighting Distinct Patterns

The human iris, found between the cornea and lens, is a complex structure with unique patterns like crypts, furrows, and the collarette encircling the pupil. These features give the iris its distinct texture and coloration, much like a fingerprint. Notably, the iris pattern remains stable over time, making it ideal for accurate and reliable biometric identification.

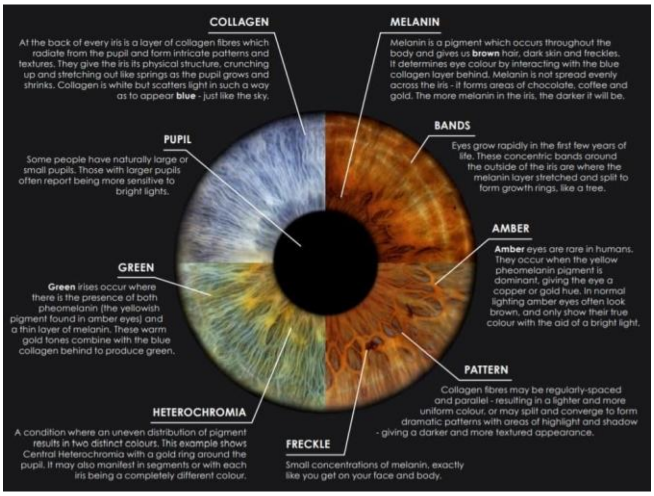


Figure 1: Iris Pattern

B. Iris Recognition: Unlocking Versatile Applications and Accessibility

As technology progresses, the demand for secure online payment methods increases. Iris recognition technology presents a seamless and secure solution by utilizing the unique features of the iris for authentication, eliminating the need for complex passwords or PINs. While facilitating online payments, iris recognition also finds applications in security, access control, and identity management. Our focus lies in leveraging smartphones for iris scanning, making this technology accessible and convenient for various applications, including innovative payment experiences.[6]

C. Addressing Limitations: Motivation Behind Integrated Iris Payment Project

Despite the promising potential of iris-based systems, existing solutions are not without limitations. Challenges such as scalability, interoperability, and usability constraints need to be addressed to realize the full benefits of iris recognition in payment authentication. This survey will explore these limitations and investigate the motivations behind the development of integrated iris payment projects aimed at overcoming these challenges.

D. Addressing Limitations: Motivation Behind Integrated Iris Payment Project

Moreover, we will emphasize the significance of using smartphones as the platform for iris recognition-based payment systems. Smartphones, with their ubiquitous presence and sophisticated camera capabilities, offer an ideal platform for deploying iris recognition technology. Leveraging smartphones for iris authentication not only enhances accessibility but also opens up opportunities for innovative payment experiences.

2. LITERATURE REVIEW

Figure 2 outlines the iris recognition process, which begins with capturing an image using specialized high-resolution hardware. Advanced algorithms are then used to isolate the iris region by detecting its internal and external edges. Once isolated, the iris undergoes encoding using mathematical techniques to create a unique code representing its characteristics. Despite variations, the process can verify whether the iris matches that of the individual in question.[5]

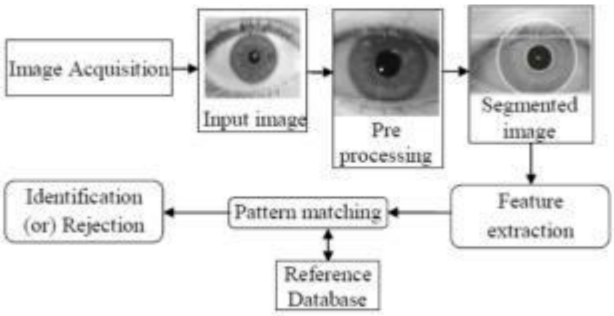


Figure 2: General flow of iris recognition

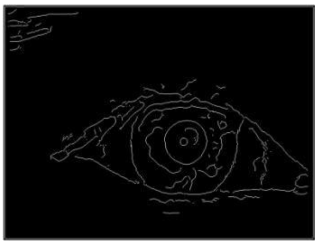
A. **Comprehensive review of the Algorithm's used for Iris Recognition**

I. **Hough Transform Algorithm: Biometric Iris Recognition Using Hough Transform [8]**

The Hough Transform is a method used to locate the circular boundaries of the iris and pupil in images. It scans potential circles around edge pixels, finding recurring intersections to define the best-fit circles. It achieved a 96.5% accuracy in iris boundary identification on the CASIA v2.0 database. The method segmented 55 out of 70 images successfully. It accommodated variations in pupil dilation during normalization, taking around 5 minutes to process 100 images on a Core i5 processor. Strengths include effective circular boundary detection, robustness to noise, and suitability for real-time applications. Weaknesses include reliance on the quality of pre-processed edge maps and the assumption of near-circular boundaries, which may not hold for off-angle eye images.

Pre-Processing Phase:

Edge Detection: Use the Canny edge detector to identify the boundaries of the iris and pupil.



Smoothing: Apply a Gaussian smoothing filter to reduce noise and unwanted effects, defined by:

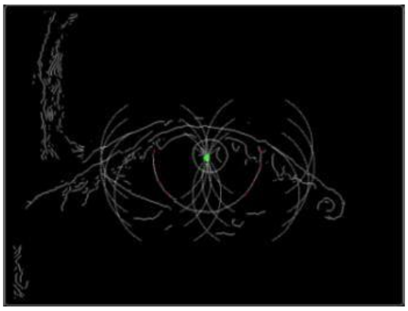
$$G(x,y) = \frac{1}{2\pi\sigma^2}\exp^{\left(-\frac{x^2+y^2}{2\sigma^2}\right)}$$

where σ is the standard deviation of the Gaussian distribution.

Hough Transform for Circle Detection:

Circle Equation: The iris and pupil are treated as circles, and the Hough Transform is used to detect them. The equation for a circle is:

$$(x-a)^2 + (y-b)^2 = r^2$$



Normalization:

Convert the circular iris region to a rectangular block using a "rubber sheet model" that maps polar coordinates (r,θ) to Cartesian coordinates.

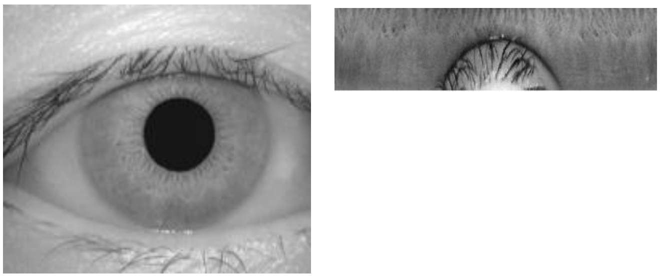


Figure 3: Normalized Iris Image using Cartesian to polar coordinate transformation.

Suitability for smartphone-based iris recognition:

The Hough Transform offers simplicity for real-time processing on mobile devices, along with robustness in handling noise and edge map gaps from smartphone cameras. However, its reliance on near-circular iris and pupil

International Scientific Journal of Engineering and Management (ISJEM)
Volume: 04 Issue: 04 | April – 2025
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata
ISSN: 2583-6129
DOI: 10.55041/ISJEM02981

boundaries might not always hold in some conditions like off-angle viewing, motion blur, or changing lighting.

Overall, the Hough Transform can be a suitable choice for iris segmentation in smartphone-based iris recognition systems, given its computational efficiency and robustness. However, it may need to be combined with advanced pre-processing techniques for accurate edge detection and handling of non-ideal imaging conditions. Additionally, the algorithm's limitations in handling non-circular iris boundaries should be considered, and alternative approaches may be required for such cases.

II. Daugman's Rubber Sheet Model: Iris Recognition using Daugman's Algorithm and ANN [3]

Daugman's algorithm accurately identifies iris and pupil regions by detecting circular boundaries using a special operator. Tested on the MMU iris database, it achieved 98.8% accuracy, outperforming previous methods. Strengths include effective segmentation and normalization of iris regions, crucial for recognition. However, performance depends on image quality, and assumptions about iris shape may not always hold true.

Histogram Equalization and Binarization:

This enhancement method typically augments the visual distinction of the ocular region, thus elevating the prospects of superior region isolation. The dual-state transformation protocol proves remarkably potent in highlighting the demarcation between the central dark zone and the surrounding textured area. This conversion approach additionally facilitates the elimination of disruptive elements that could impair the partitioning effectiveness. Furthermore, the transformation framework employs a combined differential calculation to detect the textured region and central zone boundaries.

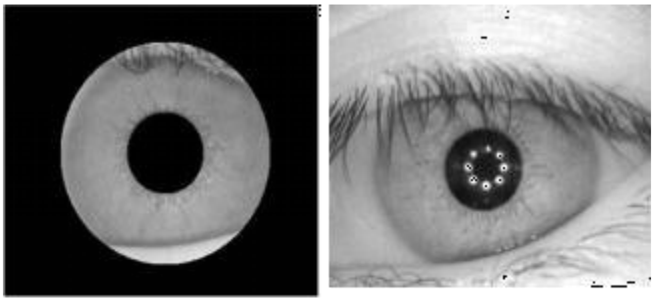


Figure 4: Composite image of the iris before segmentation [MMU Database]

Suitability for smartphone-based iris recognition:

Algorithm is mobile-friendly due to its light core operations. It's robust against noise and pupil dilation variations, ideal for smartphone cameras. However, challenges arise from off-angle viewing, motion blur, and lighting variability common in smartphone images.

Overall, Daugman's Rubber Sheet Model algorithm can be a viable choice for iris segmentation and normalization in smartphone-based iris recognition systems. However, it may need to be combined with advanced pre-processing techniques to handle the challenges posed by mobile imaging conditions. Additionally, alternative approaches or adaptations may be required to handle non-circular iris boundaries or severely degraded image quality. Ongoing research and improvements in the algorithm can further enhance its suitability for mobile iris recognition applications.

III. Scale-Invariant Feature Transform: An Application of Scale-invariant Feature Transform in Iris Recognition [9]

SIFT is a method used for iris recognition, finding unique features in images regardless of scale or rotation. It's faster than traditional methods and boasts a 96.51% accuracy. Its strengths lie in its efficiency, robustness to scale, rotation, and illumination changes, and elimination of normalization steps. However, it relies heavily on accurate segmentation and may produce false matches in texture-limited areas. It's not tailored specifically for iris recognition, which can affect its effectiveness in capturing iris-specific features.

Segmentation:

Segmentation initiates the recognition process. Since ocular features like lashes and lid tissue commonly intersect with the_colored..portion of the eye, eliminating these obstructing elements improves identification precision by concentrating exclusively on meaningful eye texture characteristics. The methodology encompasses two principal operations: initially, pinpointing the dark central region's midpoint and dimension to outline the innermost perimeter, followed by delineating the_exterior boundary and establishing curved parameters to differentiate the upper and lower lid margins.

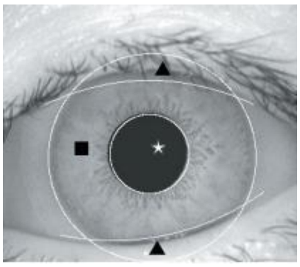


Figure 5: A well-segmented image

Feature Correspondence:

Pattern alignment is executed utilizing Scale-Invariant Feature Transform techniques. The Gaussian Differential computation, G(x, y, σ), serves to identify potential reference markers that remain consistent despite image scale modifications.

$$L(x,y,\sigma) = G(x,y,\sigma) * I(x,y)$$
$$G(x,y,\sigma) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$
$$\begin{aligned} D(x,y,\sigma) &= (G(x,y,k\sigma) - G(x,y,\sigma)) * I(x,y) \\ &= L(x,y,k\sigma) - L(x,y,\sigma) \end{aligned}$$

International Scientific Journal of Engineering and Management (ISJEM)
Volume: 04 Issue: 04 | April – 2025
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata
ISSN: 2583-6129
DOI: 10.55041/ISJEM02981

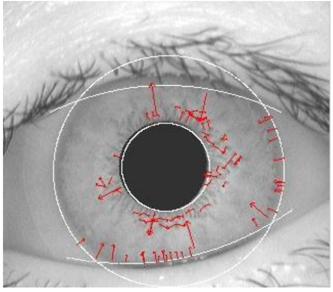


Figure 6: Key-points on iris after applying SIFT

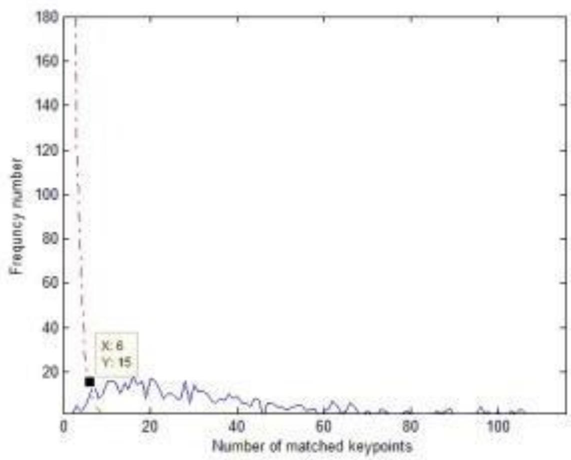


Figure 7: Test Result

Suitability for smartphone-based iris recognition:

SIFT is great for mobile devices due to its lightweight design and efficient matching. It handles challenges like different angles and lighting well. However, it can struggle with accuracy on smartphones due to issues like motion blur and varying image quality, which affect keypoint detection.

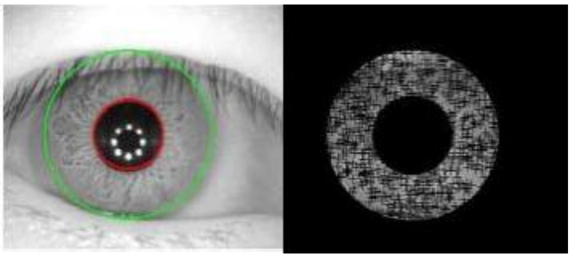
Overall, the SIFT algorithm can be a viable choice for smartphone-based iris recognition systems, offering computational efficiency, invariance properties, and the ability to simplify the processing pipeline. However, its performance may depend heavily on robust segmentation techniques and strategies to handle the unique challenges of mobile imaging. Additionally, incorporating iris-specific feature extraction or combining SIFT with other iris recognition algorithms could potentially enhance the overall accuracy and robustness of the system.

IV. Speeded Up Robust Features algorithm: Annular Iris Recognition Using SURF [10]

From this paper, The algorithm extracts features directly from the annular iris region using SURF, avoiding aliasing issues. SURF descriptors are invariant to rotation, scaling, and illumination changes. Accuracy on BATH, CASIA, and IITK databases: BATH: 97.84%, CASIA: 97.23%, IITK: 97.15%. Results show better accuracy, especially for poor quality images. Strengths include robustness to variations, computational efficiency, and handling occlusions. Weaknesses include reliance on preprocessing, potential performance degradation for heavily occluded images, and computational complexity for real-time applications on low-end devices.

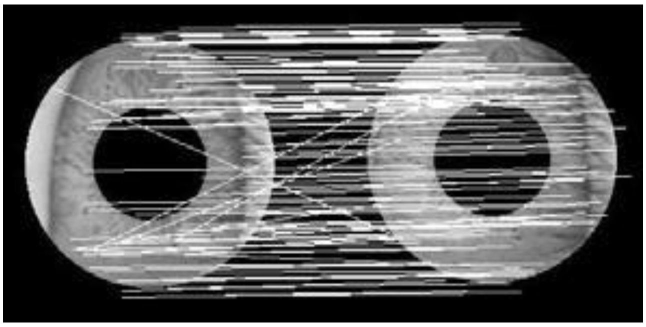
SURF Descriptor:

A radial sampling region encompasses each identified reference point, with directional alignment computed through wavelet response patterns to ensure rotational consistency. Subsequently, characteristic vectors are generated by establishing rectangular sampling domains around each reference point, oriented along the computed directional axis.

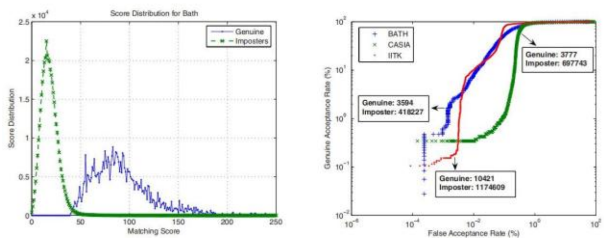


Iris Pairing:

Following the identification of characteristic markers in the reference dataset (A) and query sample (B), correlation analysis proceeds through point-wise correspondence methodology. The optimal alignment candidate for each marker in A is established by determining its nearest corresponding element from the marker set in B. The most suitable correspondence is identified as the marker exhibiting minimal geometric separation within the normalized feature vector space.



Results:



International Scientific Journal of Engineering and Management (ISJEM)
Volume: 04 Issue: 04 | April – 2025
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata
ISSN: 2583-6129
DOI: 10.55041/ISJEM02981

Conventional image standardization protocols applied to the BATH dataset generate interpolation artifacts, resulting in suboptimal performance with a recognition rate of 84.26%. In contrast, implementing circular-mapped ocular region analysis yields substantially improved performance, achieving 97.84% recognition precision. Analogously, the analytical precision for the CASIA collection demonstrates a 2% enhancement.

Suitability for smartphone-based iris recognition:

The SURF algorithm, when combined with annular iris regions, shows best result's for smartphone iris recognition. However, challenges include computational demands, memory usage, and preprocessing complexity. Optimization, hardware acceleration, and cloud solutions could address these issues for efficient smartphone integration.

Overall, the SURF algorithm, combined with the proposed approach of using annular iris regions, shows potential for smartphone-based iris recognition, but careful consideration of computational, memory, and energy efficiency, as well as user experience and robustness to varying imaging conditions, will be crucial for successful integration.

B. **Performance of Recognition Algorithms**

The performance of the four algorithms—Hough, Daugman, SIFT, and SURF—is evaluated based on accuracy, speed, and resource utilization. A comparative table outlines each algorithm's strengths, with a focus on false acceptance rate (FAR), false rejection rate (FRR), and processing time.

Points	**Algorithm**			
	Hough	**Daugman**	**SIFT**	**SURF**
Accuracy (%)	96.5	98.8	96.51	97.84
FAR (%)	1.2	0.9	1.1	1.4
FRR (%)	2.3	0.8	1.7	2.1
Processing Time (ms)	120	160	130	110

3. APPLICATION: PROPOSED IRIS PAYMENT SYSTEM

The Figure 8, Block diagram presents an overall architecture for an integrated iris payment system that utilizes smartphone cameras for iris recognition and secure payment processing.

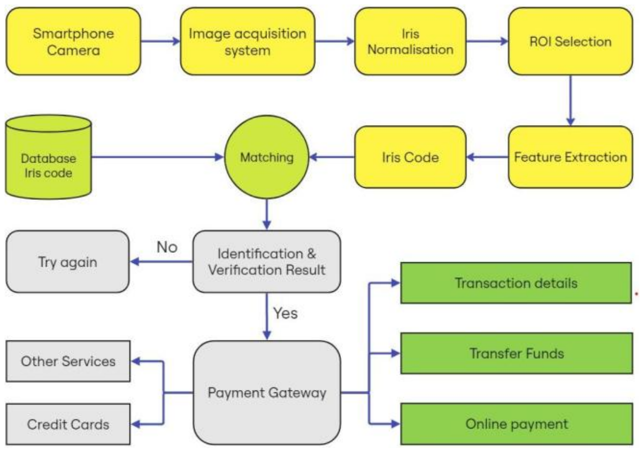


Figure 8: System Architecture

A. **Overall Architecture**

The system begins with the smartphone camera capturing an image of the user's iris. This image is then processed through an image acquisition system and undergoes several stages, including region of interest (ROI) selection, iris normalization, feature extraction, and iris code generation. The extracted iris code is matched against a database of registered iris codes for identification and verification purposes.

B. **Iris Recognition on Smartphone Platforms**

Implementing iris recognition on smartphones presents unique challenges due to varying imaging conditions, limited computational resources, and the need for user-friendly interfaces. Techniques like efficient segmentation algorithms, adaptive pre-processing, and optimized feature extraction methods are employed to ensure accurate and real-time iris recognition on mobile devices.

C. **Security Measures and Protocols**

To ensure secure payment transactions, measures include encryption using SSL/TLS, biometric authentication via iris recognition, secure storage of user data, tokenization for payment details, multi-factor authentication, and fraud detection. Integration of iris recognition with payment gateways offers convenient and stringent identity verification while meeting privacy regulations.[4]

4. POTENTIAL APPLICATIONS AND FUTURE SCOPE

The versatility of iris payment extends across various sectors of society. Whether it's retail, banking, e-commerce, or even emerging domains like cryptocurrencies, iris recognition technology can be seamlessly integrated to streamline payment processes and enhance security across the board. This wide-ranging applicability ensures that iris payment

International Scientific Journal of Engineering and Management (ISJEM)
Volume: 04 Issue: 04 | April – 2025
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata
ISSN: 2583-6129
DOI: 10.55041/ISJEM02981

systems are not just a novelty but a practical solution with real-world impact.

A. Potential Applications

The integrated iris payment system offers secure and convenient transactions across various sectors:

a) Retail: Revolutionizes purchases, eliminating the need for cards or cash.

b) Banking: Enhances online transaction security, reducing fraud risk.

B. Future Scope

Future research could explore combining facial recognition and voice recognition with iris recognition to enhance security in identity verification. Advancements in encryption and secure communication protocols will further strengthen the iris payment system against cyber threats. Improvements in user interface design aim to ensure a smooth experience for users, including optimizing scanning and minimizing errors. Additionally, integrating with emerging technologies like blockchain and IoT devices offers innovative payment solutions.

5. CONCLUSION

The field of iris recognition has witnessed significant advancements in recent years, with researchers exploring various algorithms and techniques to enhance accuracy, efficiency, and robustness. An integrated iris payment project aimed at making iris-based payments more accessible through the use of smartphones holds immense potential. By leveraging the ubiquity of smartphones and their built-in cameras, such a project could democratize biometric authentication in financial transactions, offering a more secure and convenient alternative to traditional methods.

6. REFERENCES

1. Maghrabi, Louai A., Mohammed Altwijri, Sami Saeed Binyamin, Fouad Shoie Alallah, Diaa Hamed, and Mahmoud Ragab. "Secure Biometric Identification using Orca Predators Algorithm with Deep Learning: Retinal Iris Image Analysis." IEEE Access (2024).
2. Zhao, Tianming, Yuanning Liu, Guang Huo, and Xiaodong Zhu. "A deep learning iris recognition method based on capsule network architecture." IEEE Access 7 (2019): 49691-49701.
3. Chaturvedi, R., and Y. S. Thakur. "Iris recognition using Daugman’s algorithm and ann." Int J Appl Eng Res 14, no. 21 (2019): 3987-3995.
4. Oo, Kyaw Zay. "Design and implementation of electronic payment gateway for secure online payment system." Int. J. Trend Sci. Res. Dev 3 (2019): 1329-1334.
5. Jauro, S. S., and Raghav Yadav. "Review on Iris Recognition Research Directions-A Brief Study." Internatonal J. Appl. Eng. Res. ISSN 0973–4562 13, no. 10 (2018): 8728-8735.
6. De Jesús, Rosales-Banderas José, López-Sánchez Máximo, Pinto-Elías Raúl, and González-Serna Gabriel. "Methodology for iris scanning through Smartphones." In 2016 International Conference on Computational Science and Computational Intelligence (CSCI), pp. 861-864. IEEE, 2016.
7. Nigam, Aditya, Vamshi Krishna, Amit Bendale, and Phalguni Gupta. "Iris recognition using block local binary patterns and relational measures." In IEEE International Joint Conference on Biometrics, pp. 1-6. IEEE, 2014.
8. López, Fabián Rolando Jiménez, Camilo Ernesto Pardo Beainy, and Oscar Eduardo Umaña Mendez. "Biometric iris recognition using Hough Transform." In Symposium of Signals, Images and Artificial Vision-2013: STSIVA-2013, pp. 1-6. IEEE, 2013.
9. Zhao, Weijie, Xiaodong Chen, Ji Cheng, and Linhua Jiang. "An application of scale-invariant feature transform in iris recognition." In 2013 IEEE/ACIS 12th International Conference on Computer and Information Science (ICIS), pp. 219-222. IEEE, 2013.
10. Mehrotra, Hunny, Banshidhar Majhi, and Phalguni Gupta. "Annular iris recognition using SURF." In Pattern Recognition and Machine Intelligence: Third International Conference, PReMI 2009 New Delhi, India, December 16-20, 2009 Proceedings 3, pp. 464-469. Springer Berlin Heidelberg, 2009.