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Speeded Up Robust Features Descriptor for Iris Recognition Systems

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Abstract

Biometric systems have gained significant attention for several applications. Iris identification was one of the most sophisticated biometrical techniques for effective and confident authentication. Current iris identification system offers accurate and reliable results based on near- infra -red light (NIR) images when images are taken in a restricted area with fixed-distance user cooperation. However, for the color eye images obtained under visible wavelength (VW) without cooperation between the users, the efficiency of iris recognition degrades because of noise such as eye blurring images, eye lashing, occlusion and reflection. This works aims to use Speeded up robust features Descriptor (SURF) to retrieve the iris's characteristics in both NIR iris images and visible spectrum. This approach is used and evaluated on the CASIA v1and IITD v1 databases as NIR iris image and UBIRIS v1 as color image. The evaluation results showed a high accuracy rate 98.1 % on CASIA v1, 98.2 on IITD v1 and 83% on UBIRIS v1 evaluated by comparing to the other methods.

Key words:

Biometrics system, Feature extraction, SURF, Iris recognition

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استخدام واصف المميزات القوية المتسرعة في انظمة التعرف على قزحية العين

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الخلاصة

اكتسبت النظم البايومترية اهتماما كبيرا لعدة تطبيقات. كان تحديد القزحية أحد أكثر التقنيات البايومترية تطوراً للمصادقة الفعالة. نظام التعرف على القزحية الحالية يقدم نتائج دقيقة وموثوق بها على أساس الصور المأخوذة بالأشعة التحت الحمراء (NIR) عندما يتم التقاط الصور في مسافة ثابتة مع تعاون المستخدم. ولكن بالنسبة لصور العين الملونة التي تم الحصول عليها تحت الطول الموجي المرئي (VW) دون التعاون بين المستخدمين، فإن كفاءة التعرف على القزحية تتأثر بسبب الضوضاء مثل صور عدم وضوح العين، و تداخل الرموش ، والانسداد بالأجفان وغيرها. يهدف هذا العمل إلى استخدام (SURF) لاسترداد خصائص القزحية في كل من صور قزحية NIR والطيف المرئي. يتم استخدام هذا النهج وتقييمه على قواعد بيانات CASIA v1and IITD v1 كصورة قزحية NIR و UBIRIS v1 كصورة ملونة. وأظهرت النتائج معدل دقة عالية (98.1 ٪) على CASIA v1, (98.2) على IITD v1 و (83٪) على UBIRIS v1 تقييمها بالمقارنة مع الأساليب الأخرى.

الكلمات الدالة

نظام القياسات الحيوية ، استخراج الميزات ، SURF ، التعرف على قزحية العين.

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INTRODUCTION

Iris recognition (IR) is now a common biometric technique used to identify people based solely on the iris texture. Iris contains more robust and special features among a variety of biometric traits. Iris has received comprehensive applications, such as gate system ,borders, airports , etc. Studies have studied excellent developments in iris detection over the last decade, and some existing approaches have demonstrated up to 99% accuracy[1]. However, IR is faced with several challenges, including unregulated image acquisition. Iris acquisition is typically performed in a complex environment[2] in which an individual focuses on a distance on the camera/sensor during the captioning of images. Uncontrolled photographs with consistent image quality are not desirable. Certain portions of the iris are not captured when the eye is opened partly or defocused[3]. The usefulness of a broad range of current algorithms also depends on the precise segmentation of the iris. The surrounding considerations, such as eyelashes and eyelids, however, cover a wide region of the iris, influencing segmentation and identification. In addition, iris images also withstand occlusion, camera diffusion, distortion, variation, in contrast, movement blur, pupil dilation, and luminosity, etc. [4]. Fig1 displays several pictures of the iris sample, such as the above issues.

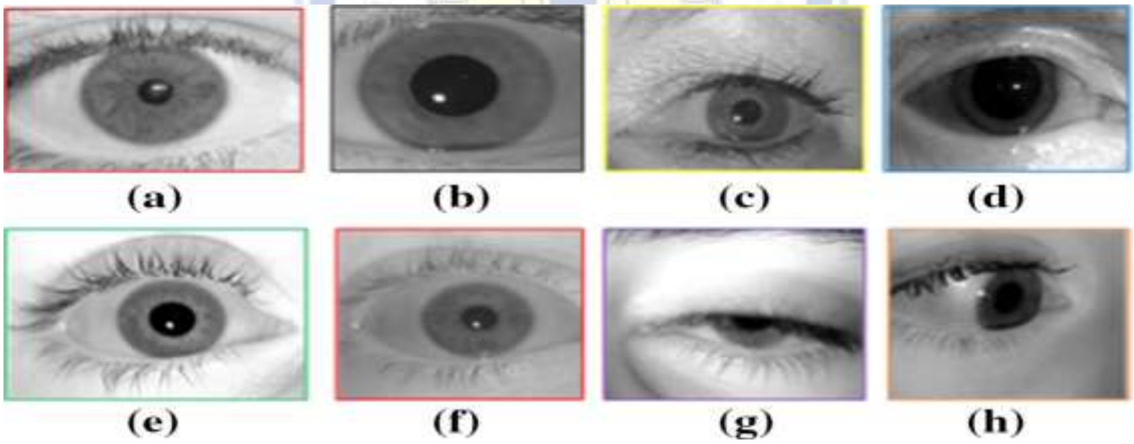

Figure. 1 Unconstrained iris images (a) reflection, (b) motion blur, (c) contrast variation, (d) pupil dilation, (e)occlusion, (f) blurred image, (g) partially open eye and (h) defocused image[1]

Distinguishing characteristics of the iris are extracted, and this process is carried out in several ways, some of which depend on statistical methods, and another part depends on signal processing.

Local characteristics are immutable in terms of size and rotation. They are good against lighting, light and slight change in image, so this works utilize the SURF feature extraction technique to perform recognition based on images from the iris. Furthermore, texture patterns

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show considerable variation between the medium and lighting conditions. There is a need to develop a matching function invariant to occlusion and transformations. Keypoint descriptors are significant and well-known object identification approaches. Interest points are detected in spatial domain. A vector descriptor is built around each key point identified for extracting transformation-invariant features.

System efficiency is measured for an accuracy rate to be reached[5], false acceptance rate (FAR), false refusal rate (FRR), and a genuine acceptance rate (GAR).

There are many ways to retrieve the properties of the iris captured by NIR, but there are a few ways to retrieve the properties of the iris in VW and NIR. So, this paper proposes to use the Speeded Up Robust Features Descriptor (SURF) method to retrieve properties in the NIR iris images, and visible wavelength (VW) iris images.

This paper is structured as follows. Section 2 gives a concise description of the proposed Iris recognition system and explain all its steps. In Section 3, results are presented and compared with existing technologies. Finally, section 4 concludes the paper.

Proposed Methodology

One of the most comprehensive human identification schemes is the Iris Recognition System. In contrast to other biometric technologies, Iris detection is a fairly recent biometric method. Compared to other biometric systems, such as the face[6], fingerprint, speech and retina, etc. Fig 2 displays the iris recognition system schematic diagram. The extraction of the Iris attribute is used to extract the most discriminating characteristic of an iris image[7]. It is a specific type of dimension reduction and provides the most information about an iris's actual image. The feature coefficient is encoded after the feature is extracted to make a convenient and accurate comparison between templates. This study focuses on extraction iris texture features taken from the database CASIA v1 and IITD v1.

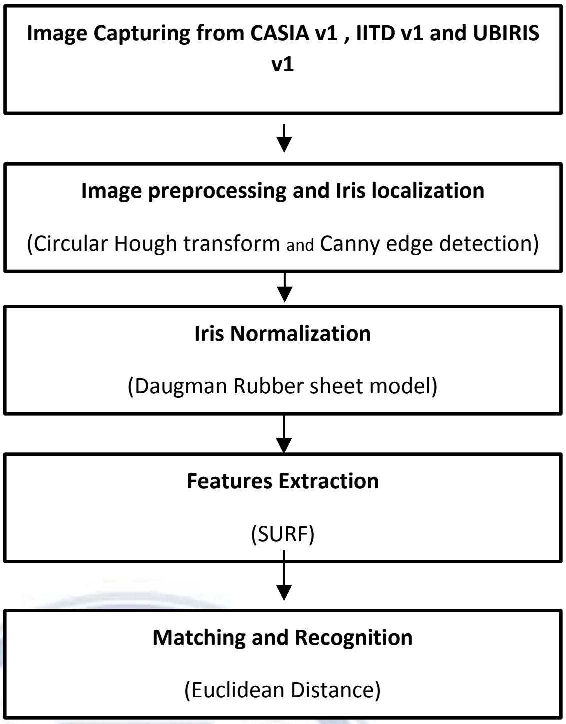


Figure .2 Iris recognition systems

Image acquisition

The first stage consists of acquiring an input image. The quality of the image affects the overall performance of the Identification system. In this work, the collection of images

from CASIA v1 and IITD v1[3]. CASIA v1 consists of 756 iris images of 108 persons and seven images each taken during two separate sessions with a difference of at least one month. Both 8-bit grey images are 320 to 280 resolution and preserved in bitmap format.

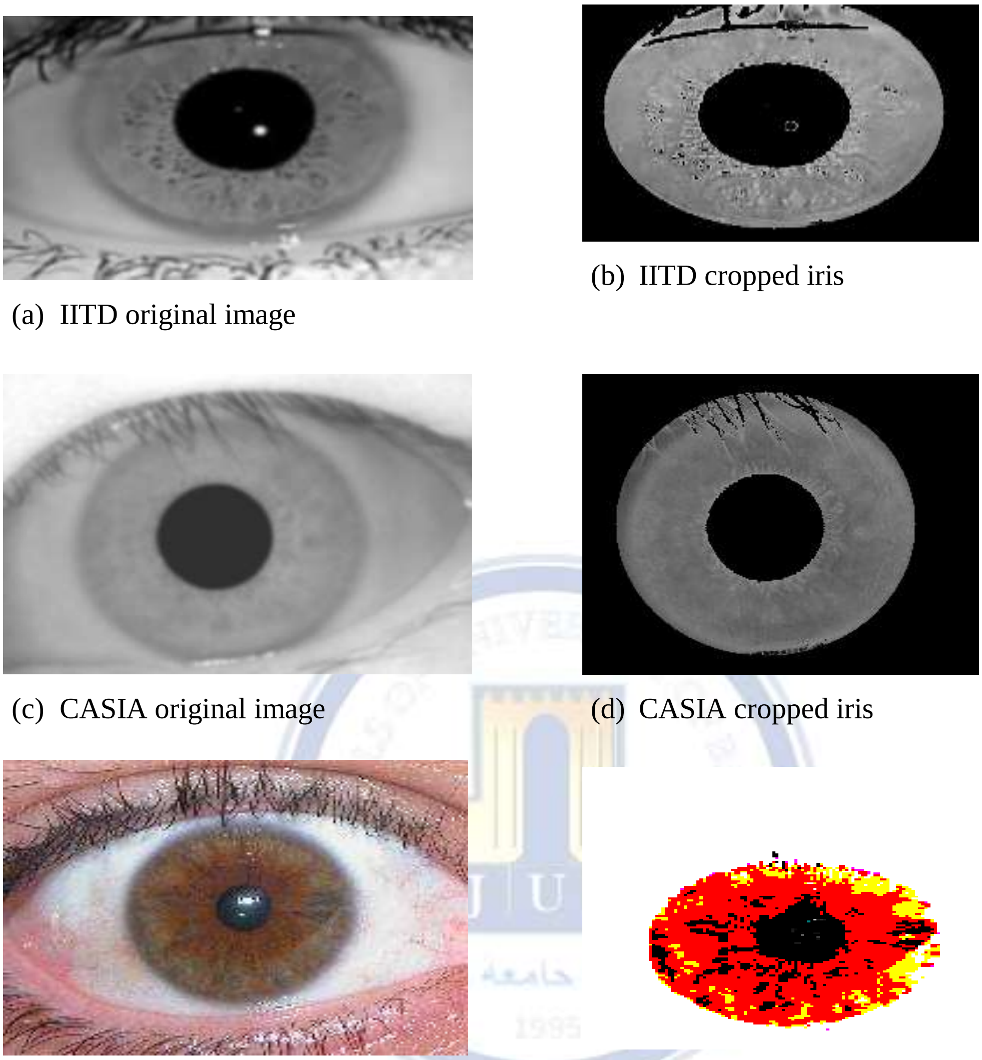
The IITD v1 image database mainly consists of iris pictures obtained from IIT Delhi students and staff. This database was compiled by JIRIS, JPC1000, and digital CMOS camera in the Biometrics Research Laboratory from January to July 2007. The collected images have been stored in bitmap format. The database includes 2,240 images from 224 different users that are freely available to researchers. In the sample, all subjects aged 14-55 years consist of 176 men and 48 women. These pictures are 320 x 240 pixels in size, and all these photographs have been acquired indoors[3].

UBIRIS.v1 contains 1877 photos obtained from 241 people in two separate sessions in September 2004. The most significant aspect is the integration of images with multiple noise factors, which simulate less restricted imaging environment. The robustness of iris reconnaissance methods can be measured. For the first capture image session, which is the enrollment phase, For the purpose of reducing noise and reflections, the capture position was changed in the second session. This enables heterogeneous images to appear in relation to reflections, Contrast, light and difficulties with concentrating[8]. CASIA v1 and IITD v1 are NIR imaging dataset, while IITD v1 are VW noisy image dataset.

Image Preprocessing and Iris localization

After the eye image has been captured or loaded, the next step is preprocessing. Images are pre-processed to enhance the machine's ability to identify characteristics and artifacts. Preprocessing can be as easy as adapting intensity, including stretching intensity, histogram equalization, noise reduction. The iris image is taken using a high-resolution camera. To delete irrelevant objects, such as the eyelash, pupil, etc., the original image must be preprocessed. Pre-processing images is a critical step in computer vision applications to eliminate the image noise and prepare the iris image for a bit of noise.

Iris location is among the essential steps in the iris recognition scheme. The inner and outer limits of the iris are located. A sclera, iris, and pupil. Colored white and out of iris, Sclera. The pupil is in the iris, and its size differs due to the strength of the light. Iris contains information about texture[9], so it must be iris and the pupil. In [10], there is an algorithm to locate the eye with a sequence of steps that can yield good results by using this method with Circular Hough Transformation (CHT)[11]. The segmentation is based on the circular Hugh Transform to detect the iris field, limited to a manually-set interval, depending on the database used. The Hough Transforms and Canny Edge detection line isolates the eyelids[12]. A threshold excludes the eyelids and possible reflections, as seen in Fig 3.



(a) IITD original image
(b) IITD cropped iris
(c) CASIA original image
(d) CASIA cropped iris
(e) UBIRIS original image
(f) UBIRIS cropped Iris

Figure.3 Original and Cropped Iris from CASIA v1, IITD v1 and UBIRIS v1 Database

Iris Normalization

Normalization involves the conversion from Polar to Cartesian Coordinates of the object. If the iris image has successfully been found, the next phase is to convert the iris region, including its eye image, to the fixed dimensions. Although there are many algorithms available, but in this work Daugman Rubber Sheet Model as used[13][14]. Figure 4 displays the model of the rubber sheet that restores points to a pair of polar coordinates inside the iris area (r, θ) where r is at the interval [0, 1] and θ is at the angle [0,2π][15][7].

The image of the iris, with its fixed size, helps the extraction technique to compare the two images of the iris[10][14]. As a results of the dilation of the pupil from changing illumination levels, dimensional differences may occur. Otherwise, dimensional incoherence can be induced within an eye socket by varying image distance, head tilt, camera rotation, and eye rotation. This means that the normalization process is necessary to provide two images of the same iris under different conditions.

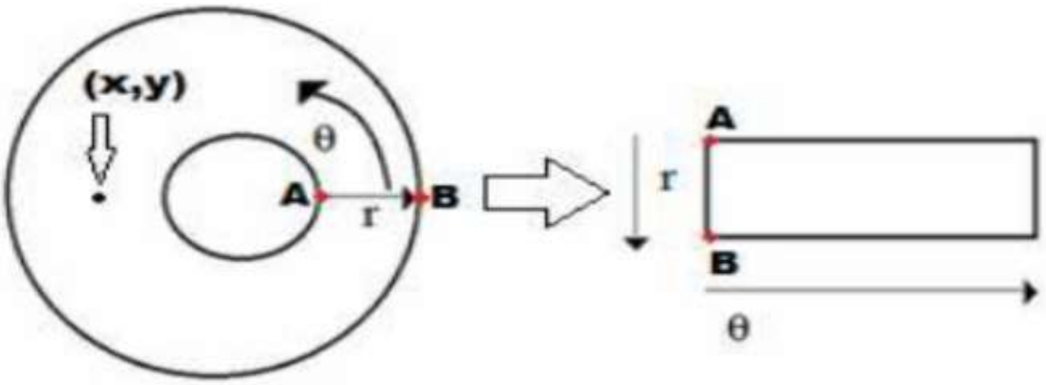


Figure.4 Daugman's rubber sheet mode[16][17]

Iris Features Extraction by SURF

The iris region is categorized as repeating occurrences by texture elements known as texels. Texels are not identical but are statistically similar. This includes a certain local extraction technique that is immutable to adjust the size, occlusion, rotation and view of two iris pictures. The local features are determined and compared to the objects around unique points known as keypoints[18]. An important feature of keypoints detectors is the ability to set the same keypoints in different conditions. The neighborhood of any position is described by a vector of features to extract features around keytexels (descriptor). This descriptor should be unique and stable in transitions, lighting and partial occlusions at the same time.

Speed Up Robust Features (SURF) is the promising approach in this paper, which has low calculating costs. Besides SIFT with a 128 dimensional vector, SURF uses just 64 dimensions. This decreases the computation time of features and allows rapid matching simultaneously with improved robustness. The SURF operator obtains keytexels from the hessian matrix and defines the haar wavelet response as a window descriptor. [18].These characteristics are highly distinctive and stable. A comprehensive explanation of the iris extraction with SURF is given below.

1-Keytexel detector:

To detect keytexels, the Hessian matrix determinant is used to select position and scale. The Hessian matrix H(P, σ) at scale σ in point P = (x, y) in an image I is defined in the equation (1)[19]:

$$\mathrm{H}(P, \sigma) = \begin{bmatrix} Lxx(P,\sigma) & Lxy(P,\sigma) \\ Lxy(P,\sigma) & Lyy(P,\sigma) \end{bmatrix} \quad (1)$$

where Lxx (P, σ) is the second-order derivative convolution with the image I at point P and Lyy (P, C) and Lxy (P, σ) are obtained similarly. The discrete approximations for 9 × 9 box filter are denoted by Dxx, Dxy and Dyy at σ = 1.2 . Convolutional filters with box filters are calculated using integral images. .A integral image at (x, y) is the sum of all the pixels above and left of (x, y)[19].

$$I_s(x,y) = \sum_{i=0}^{x} \sum_{j=0}^{y} I(i,j) \quad (2)$$

Where Is is an integral image for the input image I. By selecting the weight of the box filters appropriately, the estimates are calculated using the Hessian determinant as Equation (3)[19]:

$$\mathrm{Det}\,(H_{approx}) = DxxDyy - (0.9Dxy)^2 \quad (3)$$

Keytexels are localized across image space by applying non-maximum suppression in a 3 × 3 × 3 image space. The local maxima found in the Hessian matrix are used to approximate a localized image.

2. Keytexel descriptor

A circular window is constructed around each detected texel point and the orientation is estimated using the haar wavelet in vertical and horizontal directions. The orientation leads to the rotational invariance. SURF descriptors are also created by a rectangular window in the direction of the previously obtained orientation around each defined keytexel. To take spatial information into account, the windows are divided into 4-4 sub-regions. An extractor is applied to the horizontal and vertical Haar wavelets and their contributions are summed up. The wavelet responses are illustrated with the absolute values in order to obtain changes in the polarity of the picture intensity. The sub-image feature vector is given by Equation (4)[19].

$$V=\{\sum dx \sum dy \sum |dx| \sum |dy|\} \quad (4)$$

A function descriptor of length 64 is obtained by summarizing the descriptor vectors from all four sub-regions. The length 64 descriptor is called the keytexel descriptor for each keytexel. SURF is a very accurate descriptor used to detect iris to enhance its precision.

Matching and Recognition

The template generated also needs an appropriate Matching metric that provides a similarity measurement for the two iris models. This metric should include a range of values compared to the intra-Class comparisons and templates generated with the same eye, as well as another range of values in comparison of templates shaped by various irises. These two cases should have distinct values so that decisions about whether two models come from a single iris or two different irises can be determined with complete confidence. After characteristic extraction, feature vectors are now compared using a calculation of similarity. Euclidean distance (ED) is used for making the corresponding decision. It is the most frequently used distance. Euclidean distance measures the square root of the sum of the vector difference squares. Upon identification of keypoints, matching processes are run to find matching in the images query image (A) and stored image (B). The best match for each texel point in A is to identify the closest pair from the texel points set in B. The closest neighbor is the texel point for the invariant descriptor vector, with minimum Euclidean distance. If the Euclidean distance between the two vectors is less than a given threshold, the two descriptor are paired. The ED is determined between the vector of the test iris (VT) and the defined vector (VC) of equation (5)[17].

$$ED = \sqrt{\sum (VT - VC)^{2}} \quad (5)$$

Results and Discussion

Three tests were used to determine the efficiency of our system: False Refusal Rate (FRR), False Acceptability Rate (FAR), and Genuine Accepted Rate (GAR). FAR represent false-accepted impostor attempts, while (FRR) represent genuine wrongly refused attempts. The genuine acceptability rate (GAR) is a percentage of the actual users that the system accepts.; it is given as (100-FRR) in percent; it is also known as recognition accuracy. The results are obtained using a core i3 Cpu, and 4.00 GB of RAM.

Experiments in various databases, IITD v1, CASIA v1 and UBIRIS v1 were performed in this work. The machine tested eye images for 100 individuals. Every individual has seven photos, one for testing and the other for training. Table No. 1 presents the results obtained by testing different datasets.

Table 1: Result analysis of different databases

Database	**FAR**	**FRR**	**Recognition Rate**
CASIA v1	0.0	1.9	98.1
IITD v1	0.0	1.8	98.2
UBIRIS v1	0.0	17.0	83.0

Through the results presented in Table No. 1, we note the accuracy of the system's work while working on clear images, as in CASIA and IITD. Whereas, both CASIA and IITD users' photos were taken using NIR, which results in good quality photos with little noise.

While working on images taken using the visible spectrum of light, as is the case when working on the UBIRIS v1iris database, the images are clearly affected by the noise in the images, which leads to a reduction in GAR The presence of noise in the image greatly affects the ability to recover the characteristics of the iris well.

Comparison with existing algorithms

Iris identification system performance analysis is dependent on FAR, FRR detection rates. This technique was contrasted with other existing algorithms for iris recognition. Table 2 demonstrates the contrast of the detection rate and method of different algorithms.

Table 2: Various algorithms and their rates of recognition

Authors	**Methods**	**Recognition rate**
J.Daugman[20]	Gabor filter	100%
K. Gulmire and S. Ganorkar[21]	Gabor wavelet	99%
S.Hariprasdand .Venkatsubramian[22]	Wavelet packet	93%
Amir and Hamid[23]	Contourlet transform	94.2%
Tze Wang[24]	Haar wavelet	98.45%
Chia Te Chu[25]	LPCC	96.8%
V.Velisaulesevic[26]	Directionlets	97.4%
Proposed methods	SURF	98.1%

By comparing the proposed system with the existing systems, we note that Daugman is a method that gives the highest and best discrimination rate, but it suffers from storage problems as it uses features vectors that consist of a large number of bits and as a result also leads to an increase in the comparison time.

SURF gives a high discrimination rate, but it is lower than some of the pre-existing methods, but it does not use a large number of bits in the features vectors, and as a result, the comparison time is less and faster.

Conclusion

This paper aims to establish a robust iris recognition method, which has a different invariance. Occlusion and illumination, potential transformations. The methodology for this paper texture extracting functionality and values are added certain features have been measured accordingly. For future work, different iris characteristics can be evaluated, which also help boost system preciseness and can be checked on other databases to enhance the system activity in real-time applications .This work has been extracted in a mutual iris database. In non-cooperative databases, it must be used to verify how it operates in those databases. Other problems include shifting iris and distant iris. These databases only contain stationary images from the eye and less than 50 m from the camera to the iris. These variables must also be dealt with in the near future.

Conflict of interests.

There are non-conflicts of interest.

References:

[1] M. Choudhary, V. Tiwari, and U. Venkanna, “Enhancing human iris recognition performance in unconstrained environment using ensemble of convolutional and residual deep neural network models,” *Soft Comput.*, vol. 24, no. 15, pp. 11477–11491, 2020, doi: 10.1007/s00500-019-04610-2.

[2] R. F. Soliman, M. Amin, and F. E. Abd El-Samie, “Cancelable Iris recognition system based on comb filter,” *Multimed. Tools Appl.*, vol. 79, no. 3–4, pp. 2521–2541, 2020, doi: 10.1007/s11042-019-08163-2.

[3] M. Omran and E. N. AlShemmary, “Towards accurate pupil detection based on morphology and Hough transform,” *Baghdad Sci. J.*, vol. 17, no. 2, pp. 583–590, 2020, doi: 10.21123/bsj.2020.17.2.0583.

[4] A. A. Nithya and C. Lakshmi, “Enhancing iris recognition framework using feature selection and BPNN,” *Cluster Comput.*, vol. 22, pp. 12363–12372, 2019, doi: 10.1007/s10586-017-1619-4.

[5] H. Ansaf, H. Najm, J. M. Atiyah, and O. A. Hassen, "Improved Approach for Identification of Real and Fake Smile using Chaos Theory and Principal Component Analysis," *J. Southwest Jiaotong Univ.*, vol. 54, no. 5, 2019, doi: 10.35741/issn.0258-2724.54.5.20.

[6] O. A. H. Hayder Najm, Hayder Ansaf, "a N E Ffective I Mplementation of F Ace R Ecognition U Sing," 2019.

[7] H. M. Ahmed and M. A. Taha, "A Brief Survey on Modern Iris Feature Extraction Methods," vol. 38, no. 1, pp. 1–7, 2020.

[8] H. Proença and L. A. Alexandre, "UBIRIS: A noisy iris image database," *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 3617 LNCS, pp. 970–977, 2005, doi: 10.1007/11553595_119.

[9] M. A. Taha, "Improved Mesh _ Based Image Morphing," no. 5, 2017.

[10] M. N. Othman, "Fusion techniques for iris recognition in degraded sequences," no. March, pp. 4–5, 2016.

[11] T. Kazakov, "by A thesis submitted to University of Birmingham School of Computer Science University of Birmingham," no. May, 2014.

[12] K. Devi, P. Gupta, D. Grover, and A. Dhindsa, "An effective texture feature extraction approach for iris recognition system," *Proc. - 2016 Int. Conf. Adv. Comput. Commun. Autom. (Fall), ICACCA 2016*, pp. 1–5, 2016, doi: 10.1109/ICACCAF.2016.7749001.

[13] H. Najm, R. Hassan, and H. K. Hoomod, "Data Authentication for Web of Things (WoT) by Using Modified Secure Hash Algorithm-3 (SHA-3) and Salsa20 Algorithm," vol. 12, no. 10, pp. 2541–2551, 2021.

[14] A. Kumar, A. Potnis, and A. Singh, "Iris recognition and feature extraction in iris recognition system by employing 2D DCT," *IRJET Int. Res. Comput. Sci. Softw. Eng. Technol.*, vol. 3, no. 12, pp. 503–510, 2016.

[15] H. Najm, H. K. Hoomod, and R. Hassan, "A New WoT Cryptography Algorithm Based on GOST and Novel 5d Chaotic System," *Int. J. Interact. Mob. Technol.*, vol. 15, no. 2, pp. 184–199, 2021, doi: 10.3991/ijim.v15i02.19961.

[16] M. A. Taha, "Performance Analysis of Dynamic Source Routing Protocol," *J. Babylon Univ. Appl. Sci. No.(3)/ Vol.(25) 2017*, no. 3, pp. 814–825, 2017.

[17] M. Taha and H. Ahmed, "Second-Order Statistical Methods GLCM for Authentication Systems," *Iraqi J. Electr. Electron. Eng.*, vol. 17, no. 1, pp. 1–6, 2021, doi: 10.37917/ijeee.17.1.10.

[18] M. Bansal, M. Kumar, and M. Kumar, "2D Object Recognition Techniques: State-of-the-Art Work," *Arch. Comput. Methods Eng.*, no. 0123456789, 2020, doi: 10.1007/s11831-020-09409-1.

[19] H. Mehrotra, P. K. Sa, and B. Majhi, "Fast segmentation and adaptive SURF descriptor for iris recognition," *Math. Comput. Model.*, vol. 58, no. 1–2, pp. 132–146, 2013, doi: 10.1016/j.mcm.2012.06.034.

[20] J. Daugman, "How Iris Recognition Works," *Essent. Guid. to Image Process.*, vol. 14, no. 1, pp. 715–739, 2009, doi: 10.1016/B978-0-12-374457-9.00025-1.

[21] S. Swati and D. Gupta Deepak, “Iris Recognition Using Gabor,” *Int. J. Comput. Technol. Appl.*, vol. 4, no. 1, pp. 1–7, 2013, [Online]. Available: http://www.ijcta.com/documents/volumes/vol4issue1/ijcta2013040101.pdf.

[22] E. Rydgren, T. Ea, F. Amiel, F. Rossant, A. Amara, and I. Fea-, “IRIS FEATURES EXTRACTION USING WAVELET PACKETS Erik Rydgren , Thomas Ea , Frédéric Amiel , Florence Rossant , Amara Amara To cite this version : HAL Id : hal-02882950,” 2020.

[23] A. Azizi and H. R. Pourreza, “Efficient IRIS Recognition through Improvement of Feature Extraction and subset Selection,” no. June, 2009, [Online]. Available: http://arxiv.org/abs/0906.4789.

[24] T. W. Ng, T. L. Tay, and S. W. Khor, “Iris recognition using rapid Haar wavelet decomposition,” *ICSPS 2010 - Proc. 2010 2nd Int. Conf. Signal Process. Syst.*, vol. 1, pp. 820–823, 2010, doi: 10.1109/ICSPS.2010.5555246.

[25] C. Te Chu and C. H. Chen, “High performance iris recognition based on LDA and LPCC,” *Proc. - Int. Conf. Tools with Artif. Intell. ICTAI*, vol. 2005, no. 3, pp. 417–421, 2005, doi: 10.1109/ICTAI.2005.71.

[26] V. Velisavljevic, “Low-complexity iris coding and recognition based on directionlets,” *IEEE Trans. Inf. Forensics Secur.*, vol. 4, no. 3, pp. 410–417, 2009, doi: 10.1109/TIFS.2009.2024025.