Infant Iris Biometric Recognition System

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Can the iris be used for a secure infant recognition system?

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***Abstract This study examines the* application of infant iris biometrics as a method of identification for newborns and young children. Infant iris photos were collected using an IriShield-USB BK 2121U camera at a variety of locations, including public clinics and preschools. Before image segmentation, the quality of acquired images was evaluated. Subsequently, the traits were retrieved and matched online and the matching results were good enough to distinguish between minors two years old and older. However, the system did not show adequate recognition performance for infants under the age of two years. This approach can be used successfully to track the stability of iris traits from conception to death, as well as to identify minors from birth.**

Keywords - Infant Biometrics, Iris Recognition; Infant Iris Segmentation, Image Quality Assessment.

I. Introduction

The most distinguishing biometric an individual can have is the iris modality. It is generally acknowledged that it stands out more than the fingerprint of its parent modality. However, this claim must be verified, especially concerning young children. For biometric modalities, it is essential to determine the kind of modalities that mature much sooner than the other modalities that can mature late as the characteristics of the baby progress, since the human body develops and matures in very diverse ways. Infants' fingertips are also much softer, making it possible to create useful fingerprints with recognisable little points and ridges that can be exploited by automatic recognition systems. In contrast, is said to grow fully during six weeks of gestation. [1].

As shown in Fig. 1, universality, singularity, lasting quality, collectability, acceptability, anticipated performance, and evasion resistance should all be considered when selecting a biometric modality. In the case of the iris, it is universal, unique, and permanent unless the eyes are accidentally lost; it is collectable from a certain age range; it is acceptable in most populations worldwide; it has very high recognition performance due to its highly distinctive features; and it is also very difficult to circumvent. With technological advancements, it is critical to develop a biometric identification technology that can be used to acquire biometric features from birth. This is significant due to the high rate of child theft, child swapping in hospitals, human trafficking, and other fraudulent activities that children can access, such as grant relief [2]– [4]. In this paper, the authors address these challenges by evaluating the possibility of using the iris biometric for recognition. The success of such a system can be useful even in the home affairs system where newborns are registered based on the information received from their parents. This information is not reliable, and the birth certificate issued to parents can be forged, stolen, and lost, but the biometric will remain until the person dies.

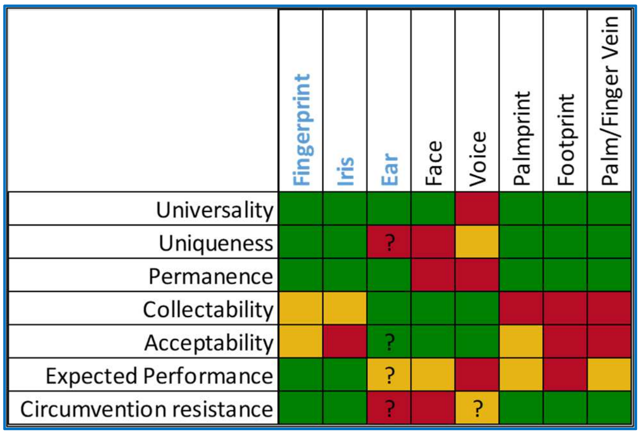

Fig. 1: Analysis of biometric modalities

The following is the rest of the work. Section II presents research related to the biometrics of the iris, Section 0 explains the strategy recommended in this paper, Section IV demonstrates the experimental findings and discusses them, and section V outlines the conclusions, suggestions, and upcoming projects.

II. Previous Infant Biometric Work

A. History of Iris biometrics

Two ophthalmologists Phlom and Safir discovered that an iris feature can be used to uniquely recognize people as young as two years old [1]. The duo approached scientists and physicists to assist them with the automated system to identify individuals with their iris biometrics. Daugman [5] – [8] filed the first iris recognition patent in 1992, and since then the iris biometric has been widely used on various platforms throughout the country. In addition to the invention filed by Daugman, researchers explored other algorithms to match and counteract what Daugman has developed[9]– [14].

Recently, recognition of the infant iris is gaining momentum due to advances in technology and the high rate of crime committed against children [2], [15]. This is very good progress in the field of biometric technology, although there are challenges perceived in this exercise.

B. Infant iris biometric recognition.

The development of an automated infant biometric recognition system has been sparked by growing interest in the identification of newborns and toddlers using the iris biometric. With the help of this biometric solution, the current challenges in the education, health care, finance and domestic affairs systems must be addressed [16] - [20] Since the present iris recognition systems were developed and evaluated in adult populations rather than children, the concerns expressed by these researchers concern the collection and processing of such data.

III. PROPOSED APPROACH

The four basic stages or phases of a standard iris recognition system are capture of the input image, segmentation, feature extraction, and feature matching, which determines if the features come from the same person or different people. The method for recognising newborn iris in this paper is as follows: in Fig. 2. This technique now includes an image quality evaluation to determine whether an input image will match the criteria for segmentation. Infants are not cooperative while collecting biometrics; therefore, this is crucial. Specifications of the quality evaluation process used in this study are available for readers' curiosity here [21]. The proposed quality assessment module is an automated process that continues if the system passes, but if the quality assessment fails, it will request another input image. This feature is important because it makes the system more robust, and it also reduces the system's computational complexity.

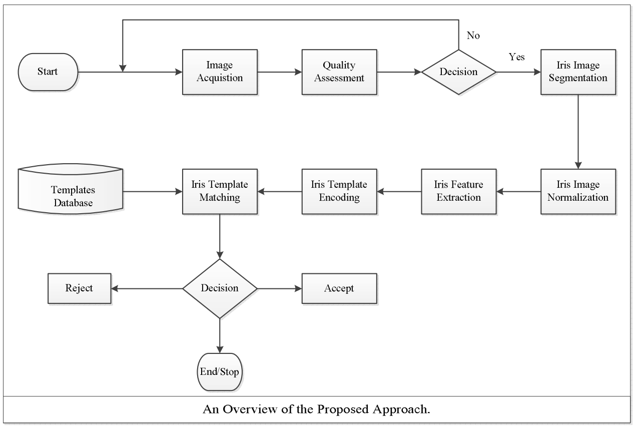

Fig. 2: Overview of the proposed infant iris recognition system

After the quality assessment module is successful, the input images are then passed to the segmentation module where the localisation of the pupil region and the iris region will be executed. The pupil itself is the darkest region of an image of the eye that is captured using an infrared camera and is visibly circular. The iris surrounds the pupillary area and is greyish. Naturally, the iris region is circular and concentric along the pupil region, but this is not always the case. These details should be considered when segmenting the iris images. Segmentation is also a very important module because the failure of this module can result in a mismatch. Iris images that have been successfully segmented are then normalised before features can be encoded to maintain the consistency of features. Once the features are extracted, the matching is done to determine whether the match results are genuine or imposter, and a decision is made.

A. Infant Iris Data Capturing Process

Public preschools, public elementary schools, and public clinics served as data collection sites. Our research institution's ethics review board, the healthcare ethics review board, and the department of education ethics review board gave their approval. The parents and guardians of the newborns also gave their consent. Three impressions of each child along with their birthdate were collected. These specifics are helpful for data training and evaluation so that conclusions about the outcomes based on age ranges can be established. The device used to acquire infant iris images was the IriShield-USB BK 2121U infrared camera depicted in Fig. 3: Because an iris is indeed an active modality that requires full participant participation, participants, as well as their parents and guardians, would exhibit resistance. Additionally, some of the photos taken with the equipment described are displayed in Fig. 3. Image acquisition from infants and young children is a time-consuming and challenging exercise because they cannot talk or even take instructions, especially from a stranger. Parents and guardians played a crucial role in helping ease up the participating subjects during the data collection process.

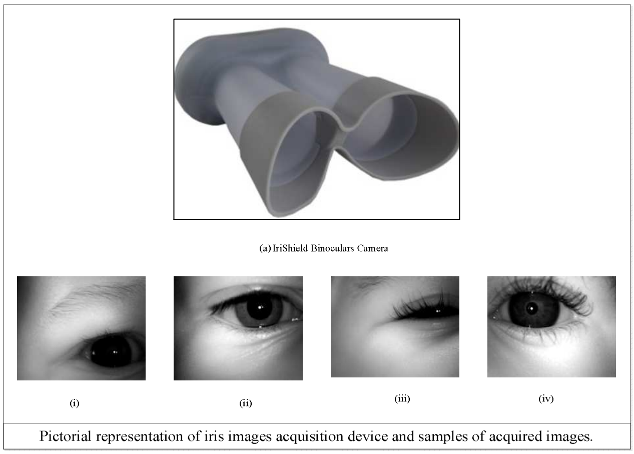

Fig. 3: The IriShield scanner (a) and samples of acquired infant iris images [(i)-(iv), (iii) show challenges of infant iris biometric acquisition].

As shown in Fig. 3, image *(i)* shows a very tender iris due to the young age of the participant, *(ii)* and *(iv)* show visible iris features that seem to be more mature than the iris depicted in *(i)*. The iris image, numbered *(iii)*, shows the partially closed eye image because the participant was not willing to provide his biometric data due to his inability to use the acquisition device.

B. Data Processing

The acquired data includes images whose eyes were partially or completely closed due to infants being sleepy, others were also scared to look at the device. Such data were removed because they were not usable but had to be recorded in case of a failure to acquire the analysis. The image numbered (iii) in Fig. 3, is an example of such an image. The usable data were then grouped so that more samples could be found per age group for analysis, as shown in TABLE I. It was difficult to obtain more data for newborns, and this is due to the device used and also the participants who were not comfortable with the data acquisition process.

TABLE I: DATA GROUPING BY AGE GROUP IN DAYS

Age group	Age range	No. of Participants
Group 1	0 < days ≤ 112	16
Group 2	112 < days ≤ 168	30
Group 3	Days >168	102

It was also much easier to capture the data from children two years old and older because some of them felt comfortable due to the presence of their parents or felt comfortable interacting with the researchers. They were also curious to play with the device and also to see how the device works. In this experiment, it can also be seen from TABLE I, based on the age group, that more data was collected from public schools than from clinics where infants were coming for immunisation and other health checks.

C. Input Image Segmentation.

The process of localising the iris region from other parts of the eye was a difficult task due to the sensitivity of the features contained in the input image. As mentioned in Section 0, the quality assessment is key before the segmentation process, as depicted in Fig. 2. If segmentation precedes quality assessment, there will be more challenges posed due to images that cannot be segmented due to poor quality, and this will, in turn, affect the recognition performance. Since most of the infant iris images are of lower quality compared to adults' images, most of the state-of-the-art segmentation algorithms do not perform well on the infant image data because they were developed and tested in adults and cooperative subjects. The output of the quality assessment modules is subsequently subjected to the segmentation module to localise the pupillary region and the iris region. The circular Hough transform was used for the location of the iris and pupil; more details on this approach can be found in [22]. Other segmentation methods, such as the Gabor filter [5]and active contour and generalized structure tensor [23]were tested but did not perform well on infant images due to the nature of the images, and the result was used for comparison purposes.

First, the pupil was detected using the intensity, and then the centre of the pupil was marked. This pupil centre is then used to localise the iris region. The rest of the eye image is removed using the calculated parameters of both the pupil and the iris. Subsequently, the pupillary regions are eliminated, leaving the segmented iris area alone, without the other eye image sections as shown in Fig. 4. The segmented iris region is then normalised using the rubber-sheet model to accommodate the dilated pupils and deformed iris regions. For the reader's interest, a detailed discussion of this approach can be found in [5]. This is important for creating a standard set of features for comparison during the feature-matching module. The output of the quality assessment module and the result of segmentation after removing other eye regions are shown in Fig. 4.

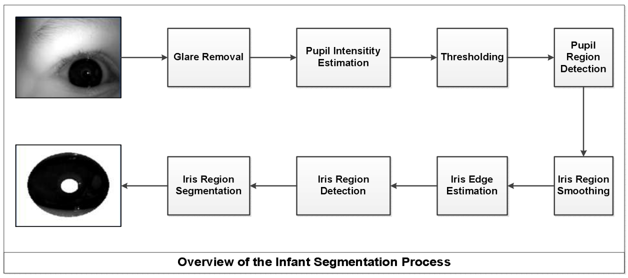

Fig. 4: Output of quality assessment and results of segmentation

D. Feature Extraction

The output of the normalised iris image is used for feature extraction using the phase-quadrant demodulation method. The pictorial representation of the process is depicted in Fig. 5.

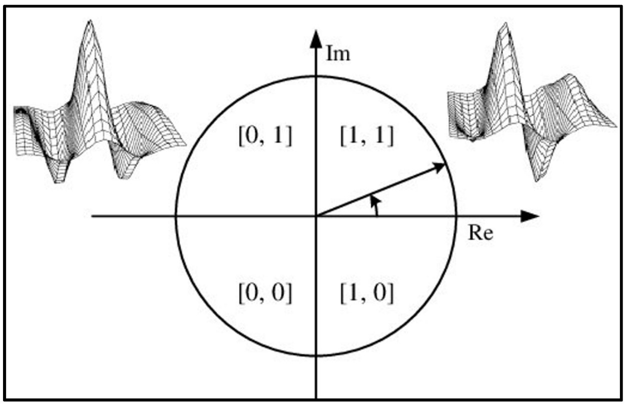

Fig. 5: Pictorial representation of the phase quadrant demodulation process [8], [24], [25]

The full details of this process and mathematical formulas can be found in [8], [24]. Details regarding the comparison of encoded templates using the minimal hamming distance matching can be found in [8], [24], [25].

IV. EXPERIMENTAL RESULTS AND DISCUSSION

In this study, several studies were carried out to verify the claim that by using newborn biometrics, babies could be recognised. Performance was assessed per group and all data was also included because the data were divided into groups so that more data could be accessible for comparison. It was crucial to evaluate the segmentation against different segmentation algorithms both with and without quality factors to determine how well the proposed system performed. In Table II, it is shown that 87% success was shown in the segmented pupillary regions and 76% in the segmented iris regions, which is much higher than competing segmentation methods such as Dauman's methods, which achieved 66% on pupil segmentation and 44% in iris segmentation. The generalised structure tensor method achieved 62% of the segmentation success in the pupil region and 49% in the iris region segmentation.

Table II: Performance measurement table of the proposed methods compared to the other competing approaches.

Key Performance Parameter	**Target Performance (%)**	**Performance without Quality Assessment (%)**	**Performance with Quality Assessment (%)**	**Competitor Daugman** [8], [24], [25]	**Competitor GST** [23]
Segmentation (pupil)	100	65	87.10	56.00	62.51
Segmentation (Iris)	100	58	76.32	44.12	49.77
EER Group 1	< 15	33.33	24.63	28.4	N/A
EER Group 2	< 10	28.25	22.28	26.4	N/A
EER Group 3	< 5	26.34	18.04	23.33	N/A
EER All groups	< 10	15.15	12.20	18.19	N/A

It is also clear in the presented table that the youngest infants' irises give higher error rates as compared to older infants. Recognition of the infant's iris improves with age. In Fig. 6, the error rates are compared for the proposed algorithm without quality assessment and also with quality assessment. These results were also compared against the state-of-the-art iris recognition system developed by Daugmna. It can also be seen that the error rates when all images are combined get higher; this is due to the youngest images included in the assessment.

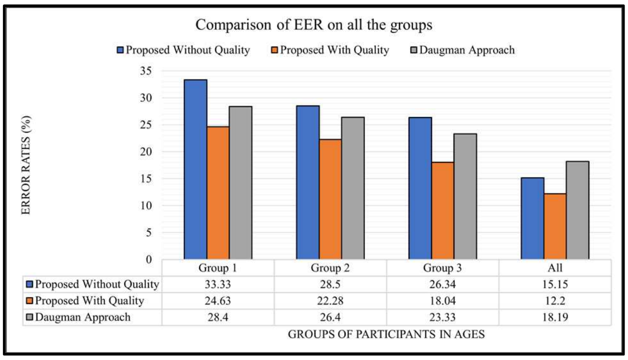

Fig. 6: Performance comparison of EER between two groups (more than two years and less than two years).

Infant iris photos older than two years offer better performance than infants younger than two years, according to the recognition performance measured in terms of EER. However, without quality monitoring, babies older than two years also have substantial errors. The features of the iris will develop more developed as people age and participants and biometric data collectors cooperate more readily. Data collection, both in terms of the device being used and of the participants, is the main bottleneck in biometric recognition using newborn iris traits. It was also noticed that, in terms of estimated error rates, the suggested approach surpasses Daugman's algorithm. However, a sizable dataset of infants and early children must be used to test the proposed methodologies.

As discussed previously, the acquisition of infant iris data acquisition is a bottleneck to the success of the development of infant biometric recognition systems. In Fig. 7: Figure, it has been shown how acquisition rates and failure to acquire compare. It should be emphasised that recognition of the iris of newborns at birth is challenging to achieve, as very young infants have extremely low acquisition rates and a significant failure to acquire rate. Additionally, infants two years old and older have fair acquisition rates, but the failure to acquire rate is still larger than the acquisition rate. This was also a result of young children playing with the acquisition tool rather than focussing on data collection. Another difficulty is that two-year-olds can be quite lively and explorative, making it difficult to complete data collection.

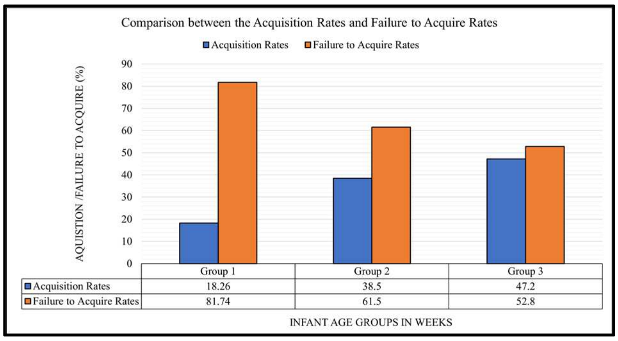

Fig. 7: Figure showing the comparison between the iris image acquisition rates (AR) and the failure-to-acquire rates (FTA).

In Fig. 8, a reference image and a query image were used to assess the effectiveness of the completely automated system, and the results were a match because the iris images belonged to the same child. The system can only produce one of two values, either 0 or 1. If the minimum hamming distance value is less than 3.2, it outputs a one (1) otherwise a zero (0). The system will determine whether a comparison is a match or a nonmatch based on these two values; in this example, it was a match.

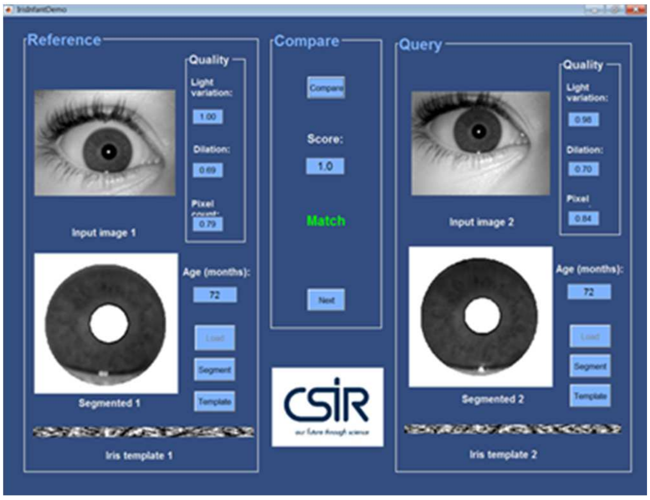

Fig. 8: Screenshot of the full testing system on an infant aged 72 months.

Demo software was also used to compare the irises of two babies, one who was 3 months old and the other 4 months old. The output was not as anticipated, hence the findings were favourable. These results are shown in the screenshot shown in Fig. *10*. The sole drawback was that it was difficult to install the system in a pilot environment since it was difficult to find infants and young children who could be used as test subjects in a real-world setting.

Fig. 9: Screenshots of the full system on two infants, one aged three (3) months and the other four (4) months.

It is significant to note that the recognition performance across all participants still has a high EER, which can provide significant difficulties, particularly for a system that is meant to function in a high-security environment. In Fig. 6, it has also been shown that children over two have a greater capacity to contribute to improved recognition performance than children under two. This simply suggests that an iris biometric cannot significantly outperform the adult child population in the population of infants.

In Fig. 10, an overview of the equal error rates describing the contribution from each group is presented. Additionally, error rates for the entire image data set are clear, and it is clear from this pie chart that infants younger than two years have low recognition performance in terms of error rates.

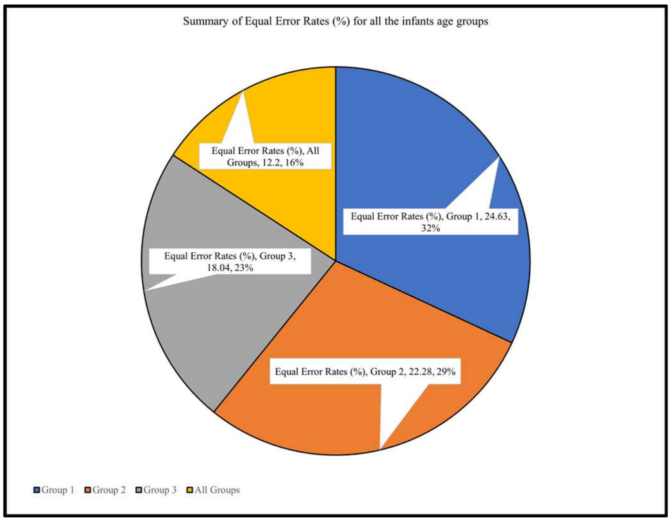

Fig. 10: Summary of the error rates for each group and all the groups with their % contribution.

V. Conclusions and Future Works

Great performance and a setback have been provided for the young field of biometric recognition. Since recognition performance is high, this work asserts that this modality can be used for recognition purposes, particularly for children two years and older. However, if the purpose is for use from birth, it must be supplemented with another biometric modality, particularly passive modalities such as facial or ear biometrics.

In the future, researchers want to gather more information and create a system to monitor how children's iris traits remain stable as they age. We will make use of other infrared iris cameras, particularly those that can capture iris from a distance. New learning-based models will be trained and created when additional data become available to improve recognition performance.

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References

[1] L. Flom and A. Safir, "IRIS RECOGNITION SYSTEM," 1987

[2] FBI, 'A Message for Parents on How to Protect Your Kids with ID Kits', *https://archives.fbi.gov/archives/news/stories/2006/july/idkits072406*, 2006. Accessed: 30 December 2022. [Online]. Available: https://archives.fbi.gov/archives/news/stories/2006/july/idkits072406

[3] A. K. Jain *et al.*, ‘Giving infants an identity: Fingerprint Sensing and Recognition”, in *ACM International Conference Proceeding Series*, June 2016, vol. 03-06-June-2016. doi: 10.1145/2909609.2909612.

[4] C. Gottschlich, T. Hotz, R. Lorenz, S. Bernhardt, M. Hantschel and A. Munk, “Modelling the growth of fingerprints improves matching for adolescents’, Aug. 2010, doi: 10.1109/TIFS.2011.2143406.

[5] J. G. Daugman, ‘High confidence visual recognition of persons by a Test of Statistical Independence,” *IEEE Trans Pattern Anal Mach Intell*, vol. 15, no. 11, pp. 1148–1161, 1993, doi: 10.1109/34.244676.

[6] J. G. Daugman, ‘Biometric personal identification system based on iris analysis’, 5,291,560, 1994 [Online]. Available: https://www.google.com/patents/US5291560

[7] J. Daugman and C. Downing, ‘Epigenetic randomness, complexity, and singularity of human iris patterns’, *Proceedings of the Royal Society B: Biological Sciences*, vol. 268, no. 1477, p. 1737–1740, 2001, doi: 10.1098/rspb.2001.1696.

[8] J. Daugman, ‘Probing the uniqueness and randomness of iriscodes: Results from 200 billion iris pair comparisons”, *Proceedings of the IEEE*, vol. 94, no. 11, pp. 1927–1934, 2006, doi: 10.1109/JPROC.2006.884092.

[9] N. N. Nelufule, ‘Combining Multiple Iris Matchers Using Advanced Fusion Techniques to Improve Iris Matching Performance’, Master Research Thesis, University of Johannesburg, Johannesburg, South Africa, 2014. [Online]. Available: https://core.ac.uk/download/pdf/54195433.pdf

[10] C. Fancourt *et al.*, ‘Iris recognition at a distance’, in *Lecture Notes in Computer Science*, 2005, vol. 3546, pp. 1–13. doi: 10.1007/11527923_1.

[11] H. Proença and L. A. Aleksandrov, “UBIRIS: A noisy iris image database”, in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2005, vol. 3617 LNCS, pp. 970–977. doi: 10.1007/11553595_119.

[12] W. Dong, Z. Sun, and T. Tan, ‘A design of iris recognition system at a distance’, in *Proceedings of the 2009 Chinese Conference on Pattern Recognition, CCPR 2009, and the First Joint Workshop on Pattern Recognition, CJKPR*, 2009, pp. 553–557. doi: 10.1109/CCPR.2009.5344030.

[13] N. Nelufule, F. Nelwamondo, T. Malumedzha, and T. Marwala, “Feature quality-based score level fusion using relative entropy measure for Iris recognition”, *International Journal of Innovative Computing, Information, and Control*, vol. 11, no. 4, pp. 1357–1368, Jul. 2015.

[14] M. Vatsa, R. Singh and A. Noore, ‘Improving iris recognition performance using segmentation, quality enhancement, match score fusion, and indexing’ *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics*, vol. 38, no. 4, pp. 1021–1035, 2008, doi: 10.1109/TSMCB.2008.922059.

[15] eNCA, ‘Matric pupil gets his identity. ‘, *eNCA, May 2016. [Online]. Available: https://www.enca.com/south-africa/matric-pupil-gets-back-his-idenity,* 2016.

[16] Y. Moolla, A. de Kock, G. Mabuza-Hocquet, C. S. Ntshangase, N. Nelufule, and P. Khanyile, ‘Biometric Recognition of Infants using Fingerprint, Iris, and Ear Biometrics’, *IEEE Access*, vol. 9, pp. 38269–38286, 2021, doi: 10.1109/ACCESS.2021.3062282.

[17] L. Beck, Ezon, L. Flom, C. Pitchford, ‘Iris Recognition Technology in Newborns’, *Invest Ophthalmol Vis Sci*, vol. 48, no. 13, 2008, [Online]. Available: https://iovs.arvojournals.org/article.aspx?articleid=2377700

[18] P. Das, L. Holsopple, D. Rissacher, M. Schuckers, and S. Schuckers, ‘Iris Recognition Performance in Children: A Longitudinal Study, *IEEE Trans Biom Behav Identity Sci*, vol. 3, no. 1, pp. 138–151, Jan. 2021, doi: 10.1109/TBIOM.2021.3050094.

[19] M. Johnson, D. Yambay, D. Rissacher, L. Holsopple, and S. Schuckers, ‘A longitudinal study of iris recognition in children’, *IEEE Trans Biom Behav Identity Sci*, vol. 3, no. 1, pp. 1–7, 2021, doi: 10.1109/ISBA.2018.8311468.

[20] T. Hutchison, ‘A longitudinal analysis on the Feasibility of Iris Recognition Performance for infants 0-2 Years Old’ 2018. [Online]. Available: https://docs.lib.purdue.edu/techmasters

[21] N. Nelufule, A. de Kock, G. Mabuza-Hocquet, and Y. Moolla, ‘Image quality assessment for iris biometrics for minors’, in the *2019 Conference on Information Communications Technology and Society, ICTAS 2019*, Apr. 2019. doi: 10.1109/ICTAS.2019.8703520.

[22] N. Nelufule, G. Mabuza-Hocquet, and A. de Kock, “Circular interpolation techniques for accurate segmentation of iris biometric images for infants”, in the *2020 International SAUPEC/RobMech/PRASA Conference, SAUPEC/RobMech/PRASA 2020*, January 2020. doi: 10.1109/SAUPEC/RobMech/PRASA48453.2020.9041135.

[23] F. Alonso-Fernandez and J. Bigun, ‘Iris boundaries segmentation using the generalised structure tensor. A study on the effects of image degradation” in *2012 IEEE 5th International Conference on Biometrics: Theory, Applications, and Systems, BTAS 2012*, 2012, pp. 426–431. doi: 10.1109/BTAS.2012.6374610.

[24] J. Daugman, ‘The importance of being random: Statistical principles of iris recognition”, *Pattern Recognit*, vol. 36, no. 2, pp. 279–291, 2003, doi: 10.1016/S0031-3203(02)00030-4.

[25] J. Daugman, ‘Recognising People by Their Iris Patterns’, in *Biometrics*, 2006, pp. 103–121. doi: 10.1007/0-306-47044-6_5.