Reanalyzing Li and Tao. (2014): Investigating Algorithm Recognition on Dark Irises

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ABSTRACT
Iris recognition algorithms have been proposed in several works with some of these algorithms solving mainly templates identification accuracy issues. The need to test these algorithms for identification or matching speed cannot be over-emphasized as this is also important when deploying algorithms in real application. This aim of this paper is to implement and validate a selected iris recognition algorithm. Performance evaluation was performed with the sole purpose of verifying the literature reported accuracy for the selected algorithm as well as to compute its identification speed on two databases (CASIA and BuIris) containing 600 iris images each. Results obtained matched the earlier 0% false acceptance with CASIA database but 42.3% with BuIris. This paper results verifies the scope of this algorithm and the need for improvement that could increase its adoptability globally.

General Terms
Algorithms

Keywords
Iris recognition; biometrics; empirical analysis; Casia; BuIris

1. INTRODUCTION
[1] define a biometrics as “a unique, measurable characteristic or trait of a human being for automatically recognizing or verifying identity”. A Biometric is regarded as unique as it exists exclusively to an individual. The unique nature of biometrics has led to a rise in the development and application of identification and verification schemes [2, 3]. Some examples of biometrics identification methods include face recognition, fingerprint scanning, voice analysis, hand geometry, retinal scanning, signature recognition. The iris is an internal organ visible from the outside, meaning the pattern cannot be altered by external factors. Its unique features and complexity makes it good enough to be used as a biometric signature [4, 5, 6, 7].

The human iris colour plays an important role in determining how effective or accurate an algorithm can be. The human iris is the circular structure and may differ colour depending on the ethnicity of individual or genetic traits as different races often have different eye colors [8]. For example, most people of African descent have brown either light, dark, or brown irises while Caucasians may have either blue, grey or green irises. It has been observed that dark brown irises do not provide enough features that can be extracted if the image was taken using Visible Length imaging, unlike lighter iris colors that can be easily distinguished. Near Infrared Cameras or sensors is therefore used to capture iris images so that the system can be able to efficiently extract the iris features' from the image. Failure to correctly capture an iris under the required specifications and amount of illumination may give rise to problems in the segmentation phase and generally affect the overall performance of the system [9].

Iris recognition is a means of identifying individuals based on distinctive patterns of the iris [10, 11]. It involves capturing an image of the individual’s iris, processing the image and simply checking existing database entries for matches as a step of verification or authentication. Iris recognition systems are already in operation worldwide, including an expellee tracking system in the United Arab Emirates, a welfare distribution program for Afghan refugees in Pakistan, and potential applications include ticketless travel, premises access control into home, office, laboratory, and others [6]. Owing to its high reliability, it has also been proposed for animals’ identification [12, 13]. It is incontrovertible that iris recognition system is the most accurate biometrics system after DNA [14, 15, 16].

Iris recognition systems encounter difficulties in reading irises of individuals with cataracts in their eyes or blind individuals. Also the cameras require a sufficient amount of Illumination to effectively capture iris images. Some of these problems can be tackled while some cannot. Most of the existing works are on iris recognition accuracy [17, 18, 19] on non-African datasets, some of them are summarized in Table 1. This paper focused on the recognition and process speed of iris algorithm besides accuracy. The performance of an existing algorithm will be studied in a different way through the use of different iris database. This research is necessary as most users may be non-cooperative [20, 7] and an accurate system would be rated low on users experience in a practical environment with large number of subjects [21].

2. METHODOLOGY
[43] algorithm was selected based on the methods used in different phases in iris recognition and the way they addressed issues with existing algorithms. Another reason is because it gave a very high average recognition accuracy of 96.5% and operational running time of 2.1 seconds. [43] method for iris recognition system uses an improved compressive sensing algorithm to achieve quick identification of iris. Extraction of iris image edge point was done using canny operator and then Hough transform was used to fit the two boundaries of the iris. The iris region is clipped, compressive sensing algorithm then is used to recognize categories of irises. Their algorithm was evaluated using metrics like False Acceptance Rate, False

Table 1. Review of existing iris recognition algorithms

Author	Summary	Method/ Algorithm	Results	Limitations/Future Works
[22]	Paper presents a non-invasive iris recognition system. This system does not require subjects to make contact with the camera or be too close to the camera for image acquisition and verification.	Using vision and control algorithms, a stereo pair of wide field-of-view (WFOV) cameras, a narrow field-of-view (NFOV) , Daugman's system for further processing.	Average verification time of a subject is 5.5 seconds.	Specularities off the frames of glasses (Eye glasses) result in false eye detection and errors. In future work, Optimization of algorithms and movement of camera would help in reducing the operational time.
[23]	This work basically entails an algorithm which is translation, rotation, and scale invariant. It aims at improving the feature extraction phase of Iris recognition.	Uses the zero crossings of the wavelet transform of the unique features obtained from the grey-level profiles of the iris.	It is computationally efficient and less sensitive to noise and quantization errors.	
[24]	This paper is focused on performance improvement of Iris recognition system. A performance evaluation is carried out on popular feature extraction methods like Gabor Transform and Wavelet Transform in order to choose a more suitable method for Iris Pattern Recognition.	Using wavelet transform , weight vector initialization and winner Selection, Competitive Learning Neural Network	Haar wavelet transform has better performance than that of Gabor transform in feature extraction and the Processing time from Data acquisition to Identification/Identification is about 2 seconds. Increased recognition performance of 98.4%	
[25]	This proposed algorithm extracts both globaland local information of the iris. Each iris image is Filtered with Gabor filters and then a fixed length feature vector is obtained.	Uses multichannel Gabor filtering	Results shows that the algorithm can effectively distinguish different persons by identifying their irises and also computationally efficient and insensitive to illumination and noise.	Future works will focus on more iris features and image sequences.
[10]	This paper deals with image processing algorithms that would improve the recognition rate of iris recognition systems.	Gradient decomposed hough transform/ integro-differential operators combination for iris localization and 2D Hilbert transform to extract textural iris information.	A total processing time of 450ms was calculated after implementation in C.	Experimental results were obtained on a small number of iris images and not on a large data set so the results cannot fully be depended on.
[26]	This paper proposes the use of Phase based matching to create an efficient Iris recognition system.	Phase components are used in the 2D discrete fourier transforms of the image	After tests on low quality images from the CASIA database, the algorithm yielded	Method to be applied mostly in multi-modal biometric systems that comprises of both Iris

			an EER (Equal error rate) of 0.58%.	and fingerprint recognition capabilities.
[27]	Different approaches were proposed and used namely gabor filters and zero crossing Representations of a discrete dyadic wavelet transform. This approaches were tested with three different pattern recognition methods	Using Gabor filters, Hamming distance and zero crossing discrete dyadic wavelet transform.	Classification success of 99.6% and EER of 0.12%.	Lack of a huge database to extensively test approaches.
[28]	This paper present an iris coding method based on differences of discrete cosine transform (DCT) coefficients of overlapped angular patches from normalized iris images.	Approach using 1D Discrete Cosine Transform (DCT)	100% Correct Recognition Rate (CRR) and perfect Receiver-Operating Characteristic (ROC) Curves with no registered false accepts or rejects. A worst-case EER of 0.000259 was also predicted.	Method was not tested on large datasets due to security or proprietary reasons
[29]	This paper proposes algorithms for iris segmentation, quality enhancement, match score fusion, and indexing to improve both the accuracy and speed of iris recognition.	Using modified Mumford-Shah functional, 1D log polar Gabor transform, Euler numbers.	Produces an overall recognition accuracy of 99.93%	
[30]	This paper proposes a method of improving performance of iris identification and verification while taking into consideration the anomalies which may occur during image capture.	Using modified Mumford-Shah functional, 1D log polar Gabor transform, Euler numbers.	Reduces the False rejection rate for verification and the computational time without affecting the identification accuracy. Combination of methods in paper gives an identification accuracy of 97.21% in 1.82secs	It adds unwanted artifacts to the high quality area of the iris image. It is also very difficult to enhance only selected regions of the image.
[31]	This proposed algorithm localizes both iris boundaries and detects eyelids then Daugman's integro-differential operator is applied	Daugman's integro-differential operator	Better performance in both recognition and iris segmentation. An iris localization time of 0.95secs	
[32]	Paper projects a detailed analysis of the effects of contact lens(colored lens and transparent) on Iris recognition performance and also recommends the use of Lens recognition algorithms	IIIT-D CLI1 database and VeriEye software were both used to evaluate the iris recognition system’s performances on various images. Existing lens detection algorithms are also used to test iris verification performance	On application of a lens detection algorithm, the recognition accuracy improves to 94.41%. However, removal of the contact lens would increase recognition accuracy.	Less Accurate lens detection algorithms gives rise for a need to develop more sophisticated contact lens detection algorithms in order to improve recognition accuracy.

[33]	This study employs artificial intelligence and effective methods in feature extraction to result in an effect iris recognition system.	Discrete cosine transform is used for feature extraction and artificial neural networks for Classification.	96% recognition accuracy with low computational costs.	
[34]	Paper is about the design and implementation of a long distance iris recognition system that can capture and process images within 30 meters. Also introduces a IAAD (Iris at a Distance) system.	Uses Daugman Algorithm, Telescope and a Wide field of View Camera.	This system gives a Hamming distance threshold of 0.33.	The small nature of the Iris becomes a challenge in image acquisition as images may not be clear enough for recognition. Because of the distance, techniques like Face Recognition, Focus Control and Image stabilization should be incorporated in the Iris recognition system to yield better results.
[35]	This paper describes a technique for implementing a wireless class attendance system using Iris recognition.	Using Daugman's Algorithm.	This method yields a verification rate of 98.3% and a rejection rate of 9.2%.	RFID technology and other biometrics technologies like retinal verifying should be worked on to enhance the reliability of recognition and adopt new wireless technologies.
[36]	This paper describes how a very fast iris recognition system can be implemented with a small template size to enable applications in small embedded systems.	Wavelet transform is used for feature extraction and Haal wavelet is also used as a mother wavelet.	A CRR of 99% was achieved on a set of samples from CASIA database. 0% FAR and 1% FRR were also achieved. Less computational complexity.	
[37]	Paper presents a new iris identification algorithm that is highly reliable.	Uses pattern-recognition techniques based on high-resolution images of the irides of an individual's eye, IER (Iris Effective Region) feature extraction used for pattern matching was compared with the stored patterns within the database.	Proposed method gives a FAR of 2% and FRR of 0%	More research in Diverse environments and configuration needs to be carried out. This algorithm cannot efficiently handle noisy or degraded images.
[9]	This paper presents the acquisition of eye-iris images of dark-skinned subjects in Africa, a predominant case of very-dark-brown iris images, under near-infrared illumination. Its aim was to create a dark-iris dataset	They created a dataset by capturing iris images of students in covenant university, Nigeria.	Total of 162 images was captured from 81 subjects	Limited number of images and a small dataset. It wasn't tested on multiple algorithms.
[38]	This paper proposes a recognition system with the use artificial intelligence.	Back Propagating Neural Network.	Algorithm gives a recognition accuracy of 99.25%.	
[39]	A new algorithm for feature extraction which reduces the effect	RED (Ridge Edge Detection) algorithm.	Claims to have a FRR of 0% and recognition	May not give optimal results when processing

	of illumination on iris images and improves the accuracy of an iris recognition system is proposed.		accuracy of 100%. Operates properly in a noise free environment	noisy images.
[40]	This paper is centered on the improvement of the Iris segmentation phase in order to increase accuracy of an Iris recognition system	Using Daugman's segmentation algorithm and Daugman's. Rubber Sheet Model, 1D Log-Gabor filters	Daugman's Algorithm based segmentation technique managed to correctly segment the iris region from 3 out of 4 eye images, which corresponds to a success rate of around 83%.	Addition of an eyelid detection system reduced the accuracy of the recognition system.
[41]	This paper proposes an iris image matching and recognition method based on local mean decomposition (LMD).	Using Local Mean Decomposition	Euclidean distances measure (MED) similarity measure achieves a CRR up to 100% when tested on CASIA database and 244 classes of ICE Database iris.	Usage of noncircular models for the iris image boundaries could improve the accuracy of the system.
[42]	Paper proposes a new technique for iris recognition	Using image moments, k-means algorithm, Neural Networks	This model exhibits an accuracy of 98.5%	
[43]	Paper proposes a highly robust algorithm which greatly reduces operational time and increases the recognition accuracy of the system.	Compressive Sensing Algorithm, Gabor filters with Principal Component Analysis (GCPA), Orthogonal Matching Pursuit algorithm.	It gave an average recognition accuracy of 96.5% and operational Running time of 2.1seconds.	
[44]	The main idea behind this paper is to recognize an individual by comparing his/her iris features with an iris feature database.	Using Complex Dual-Tree Discrete Wavelet Transform(C-DT-DWT) and both Irises of an individual to improve recognition rate	A mismatch rate of 92.25% was obtained after comparison of both irises of an individual.	
[45]	Proposes an iris recognition algorithm that not only considers the iris texture curve features, but also eliminates the influence of environment noise and reduces the feature dimension leading to a very effective system	Methods used include Curvelet, Principal Component Analysis (PCA) and Linear Discriminant Analysis(LDA)	The proposed method gave an average recognition rate of 96.30% when tested with 9 normalized samples of each individual.	

Rejection Rate, Equal Error Rate, Failure to Enroll, Gray Density Function and the overall speed (seconds).

In our case, tests were carried out on image samples taken in uncontrolled environments using a high quality iris scanner since one of the problems with most iris recognition systems is poor robustness. The captured images were uploaded into the implemented algorithm and the system output results based on similar metrics. Fig 1 shows the illustration of how the implemented the system operates.

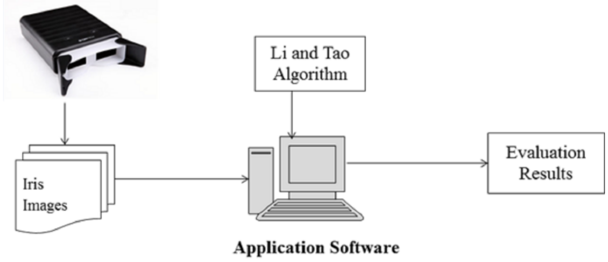


Figure 1: Implemented system operation

2.1 BuIris: The Dark-Skinned African Iris Dataset

The introductory version of the African iris dataset, called BuIris, is presented in this section.

2.1.1 Image Data Source and Data Description

The images were acquired from 300 subjects drawn from the community of Bells University of Technology, Nigeria. The left and right irises of each subject were captured at a close range, in a single session, resulting in 600 eye-iris images in bitmap format.

2.1.2 Acquisition Device and Acquisition Method

The eye-iris images were acquired and digitized by the CMITech BMT 20 dual iris scanner, shown in Fig 2. The scanner captures the right and left irises concurrently and this whole process takes less than a second to complete with full cooperation of the subjects.

Figure 2: CmiTech BMT 20 Dual Iris Scanner

Some of the specifications of the iris scanner are summarized in Table 2. Proper quality assessment, and iris segmentation which is integrated in the device SDK, ensures the iris is very visible before capturing the image. The image output also meets or exceeds the ISO 19794-6 standard. The iris scanner was connected to a PC via a USB port and operated in the manual capture mode. Environmental condition, lighting was not controlled in order to simulate a real life scenario.

Table 2. CmiTech BMT 20 Iris Scanner specifications

S/N	Attributes	Specifications
1.	Iris scanner	Dual Iris scanner
2.	Pixel Resolution	18.4 to 20 pixels/mm
3.	Spatial Resolution	Exceeds 4.0 lp/mm @ > 60% contrast
4.	Eye Safety Standard	IEC 62471, IEC 60825-1
5.	Inter-pupillary distance covered	40 to 90mm (1.6 to 3.5 inches)
6.	IR Illumination for Iris Imaging	Dual LED: wavelengths of 850 nm nominal (about 60%); and 750 nm nominal (about 40%)

3. RESULTS

Two of the important application interface of the system are shown in Fig 3 and Fig 4. Table 3 shows the parameters used in evaluating [43] algorithm and the results obtained. The result is close to the high average recognition accuracy of 96.5% obtained in the original algorithm when tested with CASIA database. Testing with BuIris images led to a higher False Acceptance Rate which represents a problem if [43] algorithm was to be generally adopted. Comparatively, the failure to enroll rate for BuIris images is also high. Table 4 compares the histogram of a BuIris and a CASIA image using 30 samples each from the two datasets; rich information area falls between 20 –170 gray levels for the BuIris and 70 – 256 gray levels for CASIA.

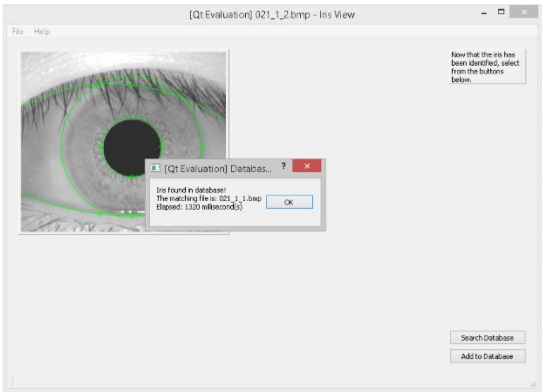


Figure 3: Application's User Interface (Showing matching time)

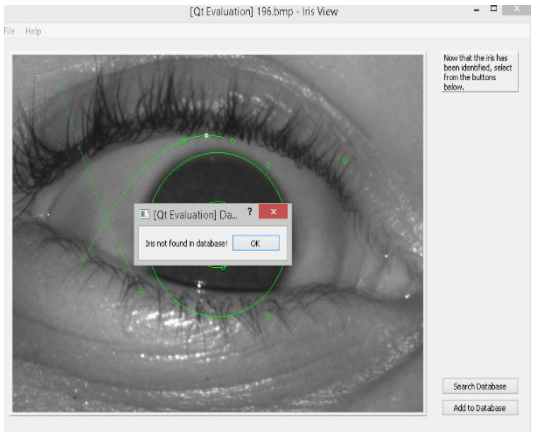
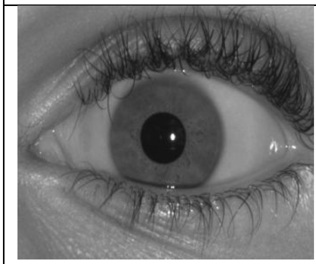
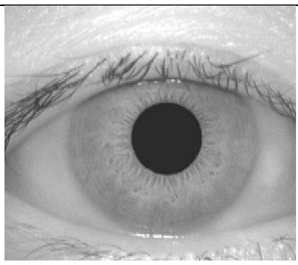
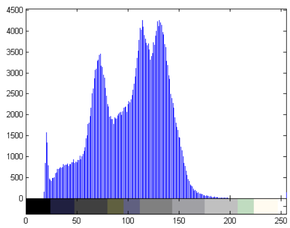
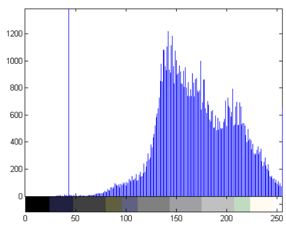


Figure 4: Application's user interface (When an Iris has not been enrolled).

Table 3. Tabular comparison of results on both BuIris and CASIA Images

Database	Number of Images	Image Format	Image Dimension	Average Matching Time (Secs)	False Acceptance Rate(%)	False Rejection Rate (%)	Failure to Enroll Rate (%)
CASIA	600	.bmp	320*280 pixels	0.8515	0	0	0
BuIris	600	.bmp	320*280pixels	0.5379	42.3	2.16	8.16%

Table 4. Histogram of selected images from BuIris and CASIA

Sample image form BuIris V1 dataset	**Sample Image from CASIA V1 dataset**
	
	

Graphs in Fig 5 and Fig 6 shows the relationship between the number of CASIA V1/BuIris images tested and the corresponding matching time(s). When the two dataset results are compared there was a clear difference in their matching time as the size of the images increases. The drops in BuIris denote the number of enrollment failures, some of which can be attributed to system error or inability to detect the iris in the image.

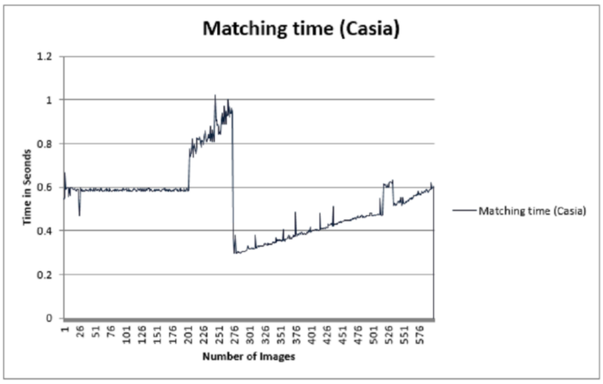


Figure 5: Graph showing matching time of CASIA against number of images (600)

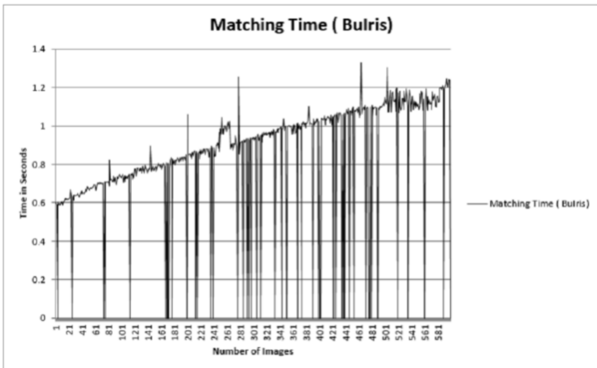


Figure 6: Graph showing matching time of BUIris against number of images (600)

4. CONCLUSION

There is a need to deploy highly efficient iris recognition algorithm due to the criticality and importance of a biometric security application. With the knowledge gained from this paper, it was found out that the selected algorithm performs efficiently when tested with images from a public database (CASIA). However, the algorithm does not perform effectively when processing iris images with dark irises and also the matching time increases as the size of the image increases.

The creation of a BuIris dataset which would also be made public could aid researchers with more training or testing datasets when developing algorithms that would function more accurately on people with dark brown irises. Future works would focus on improving this algorithm so that it would work effectively with dark irises because this would further help increase the adoption of iris recognition.

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