COMPARATIVE ANALYSIS OF TWO BIOMETRIC ACCESS CONTROL SYSTEMS

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ABSTRACT

This paper compared two Biometric Access Control Systems (BACS). The BACSs employed iris pattern for their authentication. Fast Fourier Transform-driven Access Control System (FACS) uses global iris features while Haar Wavelet Transform-driven Access Control System (HACS) uses local iris features for its template generation. Principal Component Analysis (PCA) was employed to select principal components of the extracted features (local and global). Fuzzy clustering was used for classification and Euclidean Distance (ED) as the distance metric. Experimental result showed that it took more time to train the HACS than FACS because of its intrinsic location in the iris images. It was discovered that global features driven Access Control System (FACS) with EER being 7.78 outperformed the local features driven Access Control System (HACS) with EER of 8.05. Though the two systems satisfied the benchmark of 80% for Recognition Accuracy (RA) of Biometric Systems, FACS exhibited RA of 89.87% while HACS achieved a RA of 83.83% when tested on iris images captured with CMITECH DMX-10 Portable USB 5.0 M pixel CCD Iris Camera at automatic convenient eye distances. Performance of global and local features on other biometric recognition systems can be tested and a means of combining the two features for hybridization can also be sought.

Key words: access control system, equal error rate, global features, local features, recognition accuracy

INTRODUCTION

Biometric system is automated recognition of persons based on their biological and/or behavioral characteristics (ACI, 2004; Adegoke, Omidiora, Ojo and Falohun, 2014). Different biometric properties had been used for access control some of which are: fingerprints (Nataliya, 2004; Ashraf, 2011), iris (Prashanth, *et al*., 2012). Biometric properties are useful tools for development of access control systems (Sharifah, Borhanuddin & Wan, 2012; Francisco & Homayoon, 2015). Biometrics demonstrate some advantages over conventional Electronic Access Control (EAC) which include improved security, flexibility, cost effectiveness, ease of installation, ease of marketing, high level of performance etc. (Robby, 2005).

Iris as one of the biometric properties has its applications in different areas of human day to day activities (Kelvin *et al.,* 2010). Fusion of images can be at different levels, namely pixel level fusion, feature level fusion, classification/classifier level fusion, decision level fusion, (Vaibhav and Bhiwani, 2015; Omidiora, Adegoke, Falohun and Ojo, 2015). And there are also different methods/algorithms for image fusion such as Wavelet Transform, a review of which is presented by Devyani and Malviya, (2015), Features in images can either be local features or global features (Hassaballah, *et al.*, 2016). Local features assist its biometric recognition system with the following characteristics: Locality: features are local, robustness to occlusion and clutter; distinctiveness: can differentiate a large database of the objects (*saliency*); quantitative: hundreds or thousands are located in a single image; efficient: real-time performance achievable; and generality: exploit different types of features in different situations. Their challenges among others include: repeatability; uniqueness and invariance (Alex, 2003; Tinne and Krystian, 2008; Jason, 2014). Many object recognition systems use global features that describe an entire image. Most of the shape and texture descriptors fall into this category. Such features are attractive because they produce very compact representations of images, where each image corresponds to a point in a high-dimensional feature space.

Methodology

Biometric access control systems examined in this research is iris-based. The two Access Control Systems (ACS) developed are Fast Fourier Transform (FFT) – driven Access Control System (FACS) and Haar Wavelet Transform (HWT) – driven Access Control System (HACS). The iris recognition systems consist of pre-processing stage, segmentation stage, feature extraction, classification and decision (Omidiora, Adegoke, Falohun and Ojo, 2015).

Preprocessing and Segmentation

Pre-processing performed on the images are, cropping, image enhancement, Integro-differential operators based iris segmentation for its proper boundary detection. Integro-differential operator segmentation

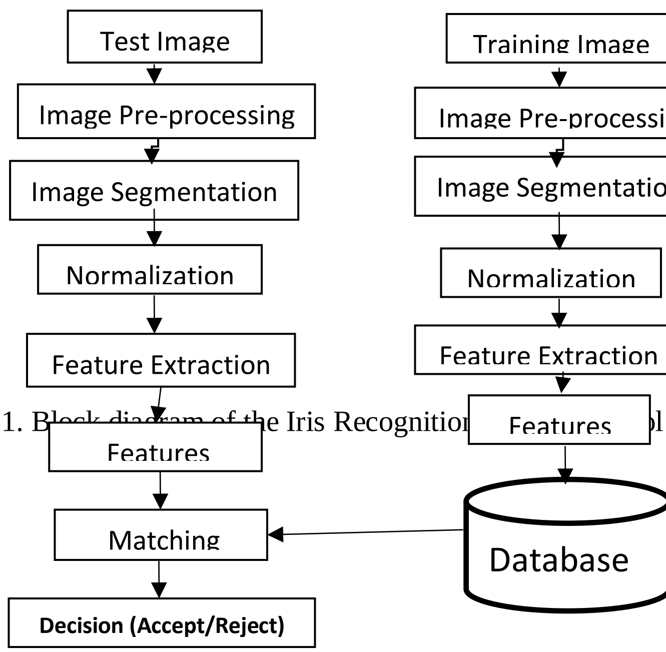

Figure 1. Block diagram of the Iris Recognition Access Control System.

(Dey and Daugman, 2004) used Integro-differential operator to deduce the radius and the center co-ordinates of the iris (1).

$$\max_{(r,x_0,y_0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x_0,y_0} \frac{I(x,y)}{2\pi r}\, ds \right| \qquad (1a)$$

where $I(x,y)$is an image containing an eye. The integro-differential operator searches over the image domain (x,y) for the maximum change in the blurred partial derivative with respect to increasing radius r of the normalized contour integral of $I(x,y)$along a circular arc ds of radius r and center co-ordinate (x_0,y_0). The symbol * denotes convolution and $G_\sigma(r)$ is a smoothing function such as a Gaussian of scale (σ) and is defined as:

$$G_\sigma(r) = \frac{1}{\sqrt{2\pi r}} e^{-\frac{(r-r_0)^2}{2\sigma^2}} \qquad (1b)$$

Rubbersheet normalization algorithm (Daugman, 2004) was used to normalize the iris images.

$$x(r,\theta) = (1-r)x_p(\theta) + rx_i(\theta) \qquad (2a)$$

$$y(r,\theta) = (1-r)y_p(\theta) + ry_i(\theta) \qquad (2b)$$

This model is called rubber sheet model which assumes that in radial direction, iris texture change linearly.

Feature Extraction

Haar Wavelet Transform (HWT) was employed to extract local features as shown in Equation (3) while Fast Fourier Transform (FFT) was used to extract global features from the iris strip as reflected in Equation (4). Local texture information, represented by energy level from each cell of the subspaces was measured with equation (3):

$$E_i = \sum_{j,k} S_i(j,k)^2 \qquad (3)$$

where E_i is energy measure for the sub-image S_i, j *is row number*; k *is column number*; S_i *is the energy level*

Global features characteristics of the iris strips was measured as Fast Fourier Transform (FFT) coefficients given as (4):

$$C_k = \frac{2}{N}\omega(k)\sum_{n=0}^{N-1} x_n Cos\left(\frac{2n+1}{2N}\pi k\right), \quad 0 \leq k \leq N-1 \qquad (4a) \text{ and}$$

$$x_n = \sum_{k=0}^{N-1} \omega(k) C_k Cos\left(\frac{2n+1}{2N}\pi k\right), \quad 0 \leq n \leq N-1 \qquad (4b)$$

where $\omega(k) = \sqrt{2}$; $k = 0$; $and\ \omega(k) = 1, \quad 1 \leq k \leq N-1$

The curse of dimensionality was reduced with the use of principal Component Analysis (PCA) as reflected in equation (5). This is to extract the principal features extracted from the iris strip before creation of the templates.

$$S = \sum_{i=1}^{n} \frac{(y_i - \bar{y})(y_i - \bar{y})^T}{n} \qquad (5)$$

where $\bar{y}$ is the data mean, such that $Sw_j = \lambda_j w_j$

Classification

Derived iris templates were classified using Euclidean Distance (ED) as shown in Equation (6):

$$ED = d(p,q) = \sqrt{\frac{1}{M}\sum_{i=1}^{M}(p_i - q_i)^2} \qquad (6)$$

where M = the dimension of the feature vector; $p_i =$ *is the database feature vector*; $q_i =$ *is the test feature vector*.

Performance metrics employed for the systems' evaluation are Average Training Time (ATT), Equal Error Rate (EER), False Acceptance Rate (FAR), False Rejection Rate (FRR), Average Recognition Time (ART) and Recognition Accuracy (RA). Each of the systems was trained with 308 images and tested with 158 images (466 in all). Table 1 showed the ATT for the developed ACS from which it was observed that FACS has a lower ATT of 9.00s compared to HACS of 10.21s. Thus, it can be deduced that HACS extracted more features for training than FACS.

Table 1 Average Training Time (ATT) of the systems

Systems	Total Training Time	Average Training Time
HACS	3060s	10.21 s
FACS	2700s	9.0s

Results and Discussion

Results of different performance metrics at various thresholds of the systems are as depicted in Table 2. It was observed that as the threshold increases, FAR increases with corresponding decrease in FRR. FAR for HACS has the least value of 0.00 between the threshold of 0.01 and

0.05 while the highest value was 17.53 at a threshold of 0.45. FACS recorded a minimum FAR of 0.00 between the thresholds of 0.01 and 0.15 while the highest is 31.82 at thresholds of 0.40 and 0.45. The RA of the systems slightly vary between 68.18% and 89.87% for FACS while it varies between 67.09% and 83.83% for HACS.

False Acceptance Rate measures the level at which imposters is erroneously accepted by the ACS system. Therefore, it implies that since HACS has a lower value of FAR, a minimal number of such imposters were accommodated compared to FACS. In like manner, False Rejection Rate (FRR) measures the rate at which legitimate enrollees were wrongly rejected. Its analysis showed that FACS had a lower False Rejection Rate (FRR). This means a minimal number of legitimate enrollees were wrongly rejected compared to HACS. These values (for both FAR & FRR) are shown in Table 2. In Figure 2, an evaluation of FAR, FRR and thresholds was carried out. The trend showed that FAR values are inversely proportion to FRR as the threshold increases. Both FRR and FAR are threshold dependent. It cannot be said that an ACS with a low FRR but high FAR performs better than another with high FRR and a low FAR. Notwithstanding, there was an intersection of the two at a certain point where FAR equals FRR i.e FAR=FRR, this is called Equal Error Rate (EER).

Different values of FAR and FRR gotten from Table 2 were observed at varying threshold values which means that the values reflected are threshold based. Meanwhile, the EER of a biometric ACS can be used to give a specific threshold independent performance measure of the ACSs.

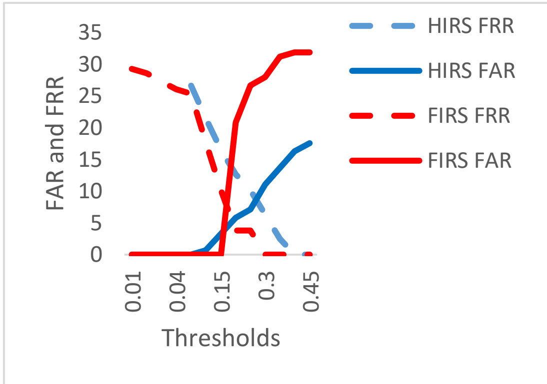

Figure 2 Comparison of Equal Error Rates (EER) of the Access Control Systems (ACS)

Table 2 Parameters of the systems at different thresholds

	***Local features ACS* (HACS)**				***Global features ACS* (FACS)**			
Threshold	**FRR**	**FAR**	**Rec_Acc**	**ART**	**FRR**	**FAR**	**Rec_Acc**	**ART**
0.01	32.91	0.00	67.09	3.49	29.22	0.00	71.00	2.88
0.02	30.38	0.00	69.62	3.50	28.57	0.00	71.43	2.87
0.03	30.38	0.00	69.62	3.48	27.27	0.00	72.73	2.85
0.04	27.85	0.00	72.15	3.53	25.97	0.00	74.03	2.86
0.05	26.58	0.00	73.42	3.43	25.32	0.00	74.68	2.72
0.10	21.52	0.65	77.83	3.47	17.72	0.00	82.28	2.48
0.15	16.46	3.25	80.29	3.56	10.13	0.00	**89.87**	2.79
0.20	12.66	5.84	80.50	3.41	3.80	20.78	75.42	2.78
0.25	10.13	7.14	82.73	3.42	3.80	26.62	69.58	2.81
0.30	6.32	11.04	82.64	3.41	0.00	27.92	72.08	2.81
0.35	2.53	13.64	**83.83**	3.42	0.00	31.17	68.83	2.78
0.40	0.00	16.23	83.77	3.45	0.00	31.82	68.18	2.79
0.45	0.00	17.53	82.47	3.39	0.00	31.82	68.18	2.74

Therefore, the EER graph of the systems were plotted as shown in Figure 2 with values of the varying thresholds against the errors (FAR & FRR). The lower the EER, the better is the system's performance. For FACS, EER was 7.75 found at 0.20 threshold while EER for HACS was 8.05 at 0.24 (Table 3). In view of the above, FACS is a better access control system than HACS. The better performance of global features driven BACS possesses distinguishing features which are used for outstanding access control systems. Though global features are sensitive to noise such as occlusion but contains outstanding features in images. They are rotation invariant texture (Ojala, Pietikainen & Maenpaa, 2002), and shape characteristics (Ravela, 2002) of the iris images. Comparison of the Training Time (TT) and the Average Recognition Time (ART) revealed that global features requires smaller training time TT and ART. Statistical comparison of the ART of the two BACS showed that at 0.05 level of significance, the significance level of 0.00 shows that the ART is significantly different for the two systems. Therefore, the null hypothesis is rejected while the alternative hypothesis is therefore upheld.

$$H_0 = There\ is\ no\ significance\ difference\ between\ the\ ART\ of\ the\ two\ BACS$$

$$H_1 = There\ is\ a\ significance\ difference\ between\ the\ ART\ of\ the\ two\ BACS$$

Table 3 Comparison of Access Control performance of the systems

Access control systems	EER	Feature types
HACS	8.05	Local features
FACS	7.75	Global features

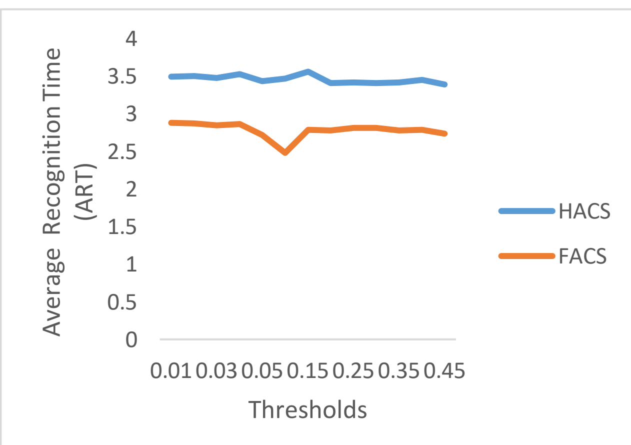

Figure 3. ART of the Access Control Systems at various thresholds

Conclusion and Recommendation

It can therefore be concluded that iris recognition systems can be employed as an Access Control System. It possesses low EER and acceptable identification and recognition accuracy, greater than 80.00%. Global image features are better features that can be employed in biometric access control systems. Apart from being easily obtainable from images, they produce a better authentication and identification system for personal identification. Notwithstanding, a means of improving the access control functionality of the biometric recognition system should be sought so as to further reduce the EER and increase the Recognition Accuracy of the systems for enhanced performance.

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