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Comparative Analysis Of Geodesic Active Contour (Gac) And Genetic Algorithm Based Geodesic Active Contour (Gagac) Segmentation Algorithms In Ethnicity Prediction System

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ABSTRACT: This work formulated an improved segmentation algorithm for iris-based ethnicity prediction system featuring the three major tribes in Nigeria. Six hundred (600) iris images from three major tribes in Nigeria (Yoruba, Hausa and Ibo) were locally captured for the database. The raw images were preprocessed by cropping and gray scaling them. The formulated Genetic Algorithm based Geodesic Active Contour (GAGAC) and standard Geodesic Active Control (GAC) were used for iris segmentation, GAC and GAGAC were evaluated using Segmentation Accuracy (SA) and Segmentation Time (ST). The performance of GAGAC and GAC were evaluated and validated using paired sample T-test statistical analysis at significance level of $p < 0.05$. The GAGAC SA and ST for Yoruba, Ibo and Hausa were 89.00%, and 14.69secs, 81.00% and 14.69secs, and 79% and 14.97secs while the corresponding values for GAC were 72.00% and 18.18secs, 65.00% and 18.11secs, and 64.00% and 17.08ses. The result of the t-test establishes the fact that there were significant differences between standard GAC and GAGAC algorithms. The developed iris based ethnicity prediction system gave an improved predictive performance.

KEY WORDS : Segmentation, GAGAC, Algorithm, Accuracy and Ethnicity

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I. INTRODUCTION

1. Introduction

A significant number of iris segmentation techniques have been proposed in the literature. Most popular techniques are based on the use of: Integro-differential operator, Hough transform and Active Contour (Samir and Arun 2009). The performance of an iris segmentation technique is greatly dependent on its ability to precisely isolate the iris from the other parts of the eye. Integro-differential operator and Hough transform rely on curve fitting approach on the edges in the image and perform better with good quality, sharply focused iris images. Also, Active Contour cannot naturally handle changes in the topology of the evolving contour. However, under challenging conditions (non-uniform illumination, motion blur, off-angle), the edge information may not be reliable (Luo *et al.* 2007). It was reported that most failures to match in iris recognition system result from inaccurate iris segmentation.

Most of the existing segmentation algorithms (such as Integro-differential operator, Hough transform and Active Contour) assumed that the iris is circular and elliptical in shape resulting in under-segmentation and over-segmentation (Lagree and Bowyer 2011; Zhang *et al.* 2011; Gugulethu *et al.* 2016; Latinwo *et al.* 2016; Singh *et al.* 2017; Latinwo *et al.* 2018). Recent segmentation algorithm like Active Shaped Model, Randomized elliptical Hough Transform and Active Contours and Geodesic Active Contour (GAC) assumed non circular and non elliptical shape of iris. However, GAC supports accurately estimating the radius of the iris and its centre thereby lessens the concerns related with the traditional models but the time required to segment the iris is high though it gives better accuracy (Minal *et al.* 2012).

This research optimized GAC as segmentation algorithm using an adaptive strategy and a global optimization technique, Genetic Algorithm (GA) to automatically determine the regularization parameters rather than the conventional manual method for each iris image in the dataset which reduces the segmentation time and increases the accuracy. This research developed segmentation algorithm called Genetic Algorithm based Geodesic Active Contour (GAGAC) which allowed GA to perform an automatic search for the optimal values of the parameters that plays an important role in GAC.

II. LITERATURE REVIEW

2.1 Segmentation

Acquired iris images may have unexpected factors which need to be eliminated before proceeding. Pre-processing techniques include, but are not limited to: eye detection; image quality enhancement such as histogram equalization or contrast stretching; and image quality evaluation. Image quality is evaluated in order to decide whether the iris image is of sufficient quality for recognition. One of the cases in which iris images are not suitable for recognition is when the eye is closed. The pre-processing techniques vary from system to system. (Ross 2010). The image preprocessing module include: iris image localization, segmentation and enhancement. Localization involves locating the iris in an eye image while segmentation involves detection and exclusion of occluding eyelids, eyelashes or reflections. (Latinwo *et al.* 2016)

The second stage of iris recognition is to isolate the actual iris region in a digital eye image. The iris segmentation is reduced to a simple search of circumference, while the search is delimited by two circumferences (usually not concentric). If the images used was adopted, the time spent in the segmentation would be minimal, but the obstructions (eyelashes, eyelids) and the physical atmosphere (reflexes, focal distances and eye movement) and variations in distances at which the image is taken may result in different image sizes of the same under some conditions and the brightness may not be uniformly distributed (Falohun *et al.* 2010).

Iris segmentation refers to the process of automatically detecting the pupillary (inner) and limbus (outer) boundaries of an iris in a given image. This process helps in extracting features from the discriminative texture of the iris, while excluding the surrounding regions. A particular image showing the pupillary and limbus boundaries are seen. Iris segmentation plays a key role in the performance of an iris recognition system. This is because improper segmentation can lead to incorrect feature extraction from less discriminative regions (such as sclera, eyelids, eyelashes, pupil), thereby reducing the recognition performance. The first stage of iris recognition is to isolate the actual iris region in a digital eye image. The iris region can be approximated by two circles, one for the iris/sclera boundary and another, interior to the first, for the iris/pupil boundary. The eyelids and eyelashes normally occlude the upper and lower parts of the iris region. Also, specular reflections can occur within the iris region corrupting the iris pattern. A technique is required to isolate and exclude these artifacts as well as locating the circular iris region (Masek and Kovesi 2003).

This research will address the issue of iris image segmentation for an improved texture extraction, as it is reported that most match failures in iris recognition system result from inaccurate iris segmentation. However, iris segmentation is the most time-consuming step in the iris recognition system and so become the bottleneck in real time environments. Iris segmentation is difficult task and faces some challenges such as specular reflection, contrast enhancement, blurred images and occlusion. Two main challenges of iris segmentation of realistic eye images are addressed: segmentation accuracy and processing speed.

A significant number of iris segmentation techniques have been proposed in the literature. Most popular techniques assumed that irises are circular or elliptical in shape, hence focusing on determining model parameters that best fit these hypothesis in the segmentation process resulting in challenging processing of non-ideal iris images resulting in under-segmentation and over-segmentation (Arun and Samir 2006). They mostly are based on using an Integro-Differential Operator, Hough transform and Active Contour. The performance of an iris segmentation technique is greatly dependent on its ability to precisely isolate the iris from the other parts of the eye. Integro-differential operator and Hough transform techniques rely on curve fitting approach on the edges in the image. Such an approach researchs well with good quality, sharply focused iris images. However, under challenging conditions (e.g., nonuniform illumination, motion blur, off-angle, etc.), the edge information may not be reliable (Samir and Arun 2009). Following important steps are involved in most iris segmentation methods.

i. Finding the pupillary boundary of the iris
ii. Finding the limbic boundary
iii. Specular reflection removal, if any
iv. Detecting and removing any superimposed occlusions of eyelashes, shadows or reflections.

It is reported that most failures to match in iris recognition system result from inaccurate iris segmentation. For instance, even an effective feature extraction method would not be able to obtain useful information from an iris image that is not segmented accurately. For better performance of the iris recognition system correct segmentation method plays vital role.

Literature reported few algorithms that do not assume circular or elliptical boundaries in iris segmentation (Active Shape Model (Abhyankar & Schuckers 2006), Randomized Elliptical Hough Transform Weighted Integro-differential Operator (Zuo *et al.* 2006), Circular Active Contour Model (Proenca & Alexandre 2006), Active Contour (Daugman 2007) and Geodesic Active Contour (GAC) (Minal *et al.* 2012) among others. However, GAC algorithm supports in accurately estimating the radius of the iris and its center thereby lessens some of the concerns related with the traditional models. The time required to segment the iris using GAC is more though it gives more accuracy (Minal *et al.* 2012). In Figure 2.12, some of the iris images from the CASIA database are shown that the pupil boundaries are not perfect circles.

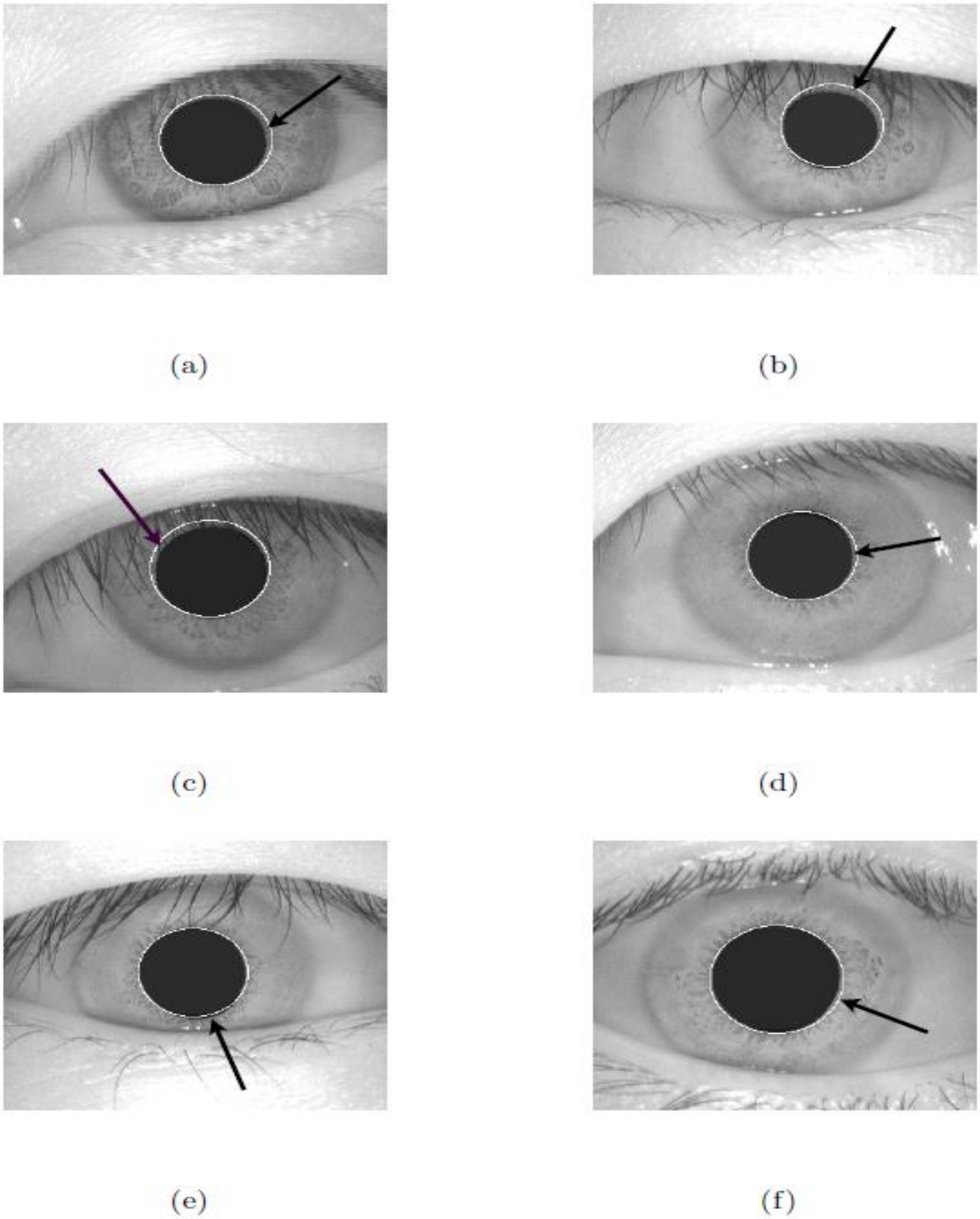


Figure 2.12: (a)-(f) Illustrate that Pupils are not Perfect Circles. CASIA Database
Source: (Arun and Samir, 2006)iris images from the CASIA database are shown that the pupil boundaries are not perfect circles.

2.2 Geodesic active contour (GAC)

The active contour model or snake is defined as an energy-minimizing spline- the snakes energy depends upon its shape and location within image. Local minima of this energy then correspond to desired image properties. Active contour models may be used in image segmentation and understanding. There are two main groups of deformable contour/surface models: active contour/snakes belong to parametric model family as borders are represented in parametric form and geometric deformable models which overcome the problems with snakes by representing developing surfaces by partial differential equations. The main feature separating geometric deformable models from parametric ones is that the curves are evolved using only geometric computations, independent of any parameterization: the process is implicit (Arun and Samir 2006).

Despite the success of Active Contour, the original parametric active contour model has some noticeable drawbacks. First, it depends not only on the intrinsic properties of the contour but also on its parameterization; thus, it is a nongeometric model. Second, it cannot naturally handle changes in the topology of the evolving contour; significant progress towards topologically adaptable parametric snakes has been done only recently. These drawbacks of standard active contours were addressed by geometric active contours, introduced in (Caselles *et al.* 1993 and Malladi *et al.* 1995). An important development has been the introduction of geodesic active contours. This approach is based on the relation between active contours and the computation of geodesics (minimal length curves). The technique is to evolve the contour from inside the iris under the influence of geometric measures of the iris image. Some of the features of GAC are given as:

i. The GAC scheme used for the detection of object boundaries.
ii. It is extensively used in medical image segmentation.
iii. Contour evolution scheme based on image content and curve regularity.
iv. Evolution terminates when contour encounters the “boundary” of the object
v. Able to detect boundary even if gaps exist in the boundary.
vi. GAC can split and merge at local minima (Samir and Arun 2009)

The iris segmentation procedure using GAC can be divided mainly into two steps: Pupil segmentation and Iris segmentation.

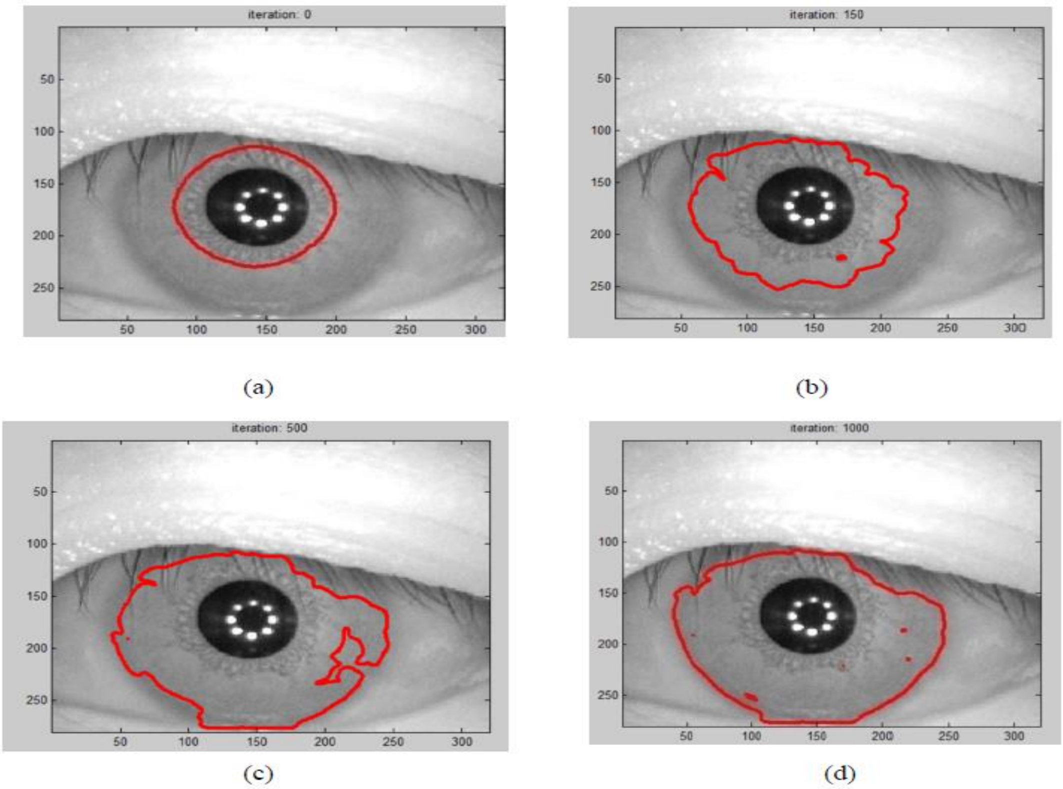


Figure 2.18: Evolution of the GAC during Iris Segmentation :(Image S1011L07 from CASIA interval version3 database)

(a) Iris image with initial contour (Zeroth level set)
(b) Contour after 150 iterations,
(c) Contour after 500 iterations,

(d) Final Contour after 1000 iterations.
Source: Minal *et al. (*2012)

2.3 Previous research on segmentation using GAC

Arun and Samir (2006) presented a novel iris segmentation scheme that employs Geodesic Active Contours to extract the iris from the surrounding structures. The proposed scheme elicits the iris texture in an iterative fashion depending upon both the local and global conditions in the image.

Samir and Arun (2009) presented a novel iris segmentation scheme employing geodesic active contours (GACs) to extract the iris from the surrounding structures. The proposed scheme elicits the iris texture in an iterative fashion and is guided by both local and global properties of the image.

Minal *et al.* (2012) focused on image segmentation using Geodesic Active Contours and comparison with traditional methods of segmentation. The iris texture was extracted in an iterative fashion by considering both local and global properties of the image. The matching accuracy of an iris recognition system was observed to improve upon application of the proposed segmentation algorithm.

Ganorkar and Prabhat (2013) discussed the methods of iris recognition method and presented the simulation results starting from the novel segmentation method which was based on use of Geodesic Active Counters (GAC) in order to extract the iris from surrounding structures. The performance experimental result measured in terms of false acceptance rate, false rejection rate showed that this proposed method of Iris Recognition is more accurate when compared to previously presented methods. The method as implemented also came with low complexity, making it superior to the other methods evaluated in terms of both speed and accuracy.

Kapil, (2015) presented a novel iris segmentation scheme employing geodesic active contours (GACs) to extract the iris from the surrounding structures. The proposed scheme elicits the iris texture in an iterative fashion and is guided by both local and global properties of the image.

Kalavathi and Bhonesh (2016) presented a simple and efficient method based on the geodesic active contour modelto segment iris from human eye image. First an edge detection method was applied to find the edges, then Hough circle transformation method was performed to identify the circular object present in the edge image and it is treated as rough eye image. Then Geodesic active contour method detected the actual eye boundary in the rough eye image.

Satish and Pullakura (2018) proposed an efficient method for the segmentation of iris images that deals with non-circulariris boundaries and other noise artefacts using the OTSU multilevel threshholding based on improved particle swarm optimisation technique as a pre-segmentation step after which Geodesic Active Contour incorporated with a novel stopping function was used to segment non-circular iris boundaries.

2.3. Related works on GAC optimization

Carl-Fredrik *et al.* (2000) introduced the use of spatially adaptive components into the geodesic active contour segmentation method for application to volumetric medical images. The research demonstrated the feasibility of incorporating local structure information into the evolution equations for level set based active contour models. However much more research is needed in order to test the method on large data sets and to improve the current implementation.

Goldenberg *et al.* (2001) proposed a Fast Geodesic Active Contour (FGAC) which was useful for object segmentation in images, like tracking moving objects in a sequence of images. The method is based on the Weickert–Romeney–Viergever (additive operator splitting) AOS scheme. It is applied at small regions, motivated by Adalsteinsson-Sethian level set narrow band approach, and uses Sethian's fast marching method for re-initialization. Experimental results demonstrated the power of the new method for tracking in color movies.

Hongliang and Pierre (2012) proposed a method termed Tubular Enhanced Geodesic Active Contours (TEGAC), which combines geodesic active contours with a speed function that is based on enhancing the "tubularity" of the continuum robot. It takes advantage of the known robot diameter along its length. It also takes advantage of the fact that the robot surface facing the ultrasound probe provides the most accurate image. The proposed approach was demonstrated through ex vivo intracardiac experiments to offer superior performance compared to conventional active contours.

Alias *et al.* (2019) proposed a fourth-order modified geodesic active contour (GAC) model to enhance the accuracy of segmentation. Experiments show that the model can accurately segment satellite images with itensity inhomogeneity and weak boundaries. However, the value of σ needs to be well chosen depending on the image because the accuracy of segmentation may be affected by reducing its computational efficiency in the segmentation process.

In this research, high segmentation time which greatly reduces the performance of GAC was addressed and overcome by developing a Genetic-Algorithm based Geodesic Active Contour (GAGAC) where the regularization parameters were determined automatically instead of manually for each image.

III. METHODOLOGY

3.1 Construction of locally acquired iris database

Six hundred (600) iris images comprising of both left and right irises of 100 subjects in Nigeria were locally captured using CMITECH Imager (camera) with high resolution in an uncontrolled environment to construct a database. Some desirable properties were aimed at considering the following precautions during image acquisition:

i. High resolution and good sharpness to enable accurate segmentation
ii. Good lighting condition i.e under controlled light intensity to prevent image distortion.

An application software (CMIRIS SDK Version 1.2.6 for Windows OS) was used to acquire and pre-process the iris image before actual image enhancement were employed and the following algorithm steps was applied:

i. Capture iris: to capture a good image on the screen
ii. Re-snap image: to re-snap an image that was wrongly or not well captured
iii. Crop iris: to manually cut off other parts of the eyes and the face mistakenly captured to reduce captured image to the required one
iv. Gray Scale: to change the image to gray scale form.
v. Save image:

All the captured images were saved into work environment to afford the iris image to be further processed. Figure 3.1 presented selected original iris images while Figure 3.2 presented selected cropped iris images with dimension 314x353.

Figure 3.1: Selected original iris images.

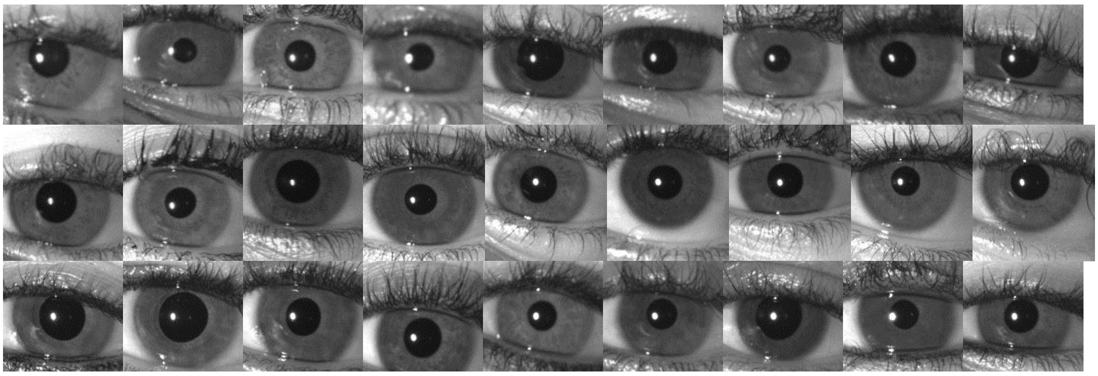


Figure 3.2: Selected cropped iris images.

3.2 Image enhancement: In order to take advantage of the characteristics of the pupil described above, the image was enhanced using histogram equilization in order to obtain a reliable binary image of the pupil.

3.3 Segmentation: This stage was taken care of using GAC and the formulated GAGAC. The segmentation methods in this research involves three major steps. First, the approximate location of the iris center is detected. Second, the iris region is extracted. Finally, the reflections (noises) are removed from the iris region. The significance of this steps is its robustness to realistic noises caused by non-ideal imaging settings such as reflections, blurred boundaries, gaze-deviation, and eyelids occlusion. Sample of segmented iris images was presented in Figure 3.3

This research came up with a new algorithm optimizing Geodesic Active Contour with Genetic Algorithm (GAGAC) at segmentation level which allowed GA to perform an automatic search for the optimal values of the regularization parameters (σ (expansion weight) for Gaussian, *k* (number of iterative time step) *and* α (contour weight)) which were normally provided by user for each image in the stopping function algorithm) that played an important role in GAC. Genetic Algorithm which is an adaptive strategy and global optimization algorithm was used to provide the best optimal value for the three parameters and these values were supplied as inputs in GAC algorithm for segmenting all the acquired images. The formulated algorithm for GAGAC is as shown in Algorithm 3.1.

Algorithm 3.1: Algorithm for GAGAC segmentation:

Phase 1: Find the Stopping function: K

1.1 Inputs: Determine the optimal value of the three parameters of GAC (σ, *k* and α)
Step 1: Find the best σ for Gaussian, best *k and* best α using GA
t := 0;
Create initial population $B_0 = (b_{1,0,...,}b_{m,0})$;
WHILE *stopping condition not fulfilled* DO
BEGIN
(∗ proportional selection ∗)
FOR i := 1 TO m DO
BEGIN
x := Random[0,1];
$k := 1$:
WHILE $k < m \,\&\, x < \sum_{j=1}^{k} f(b_{j,t}) / \sum_{j=1}^{m} f(b_{j,t})$ DO
k := k + 1;
$b_{i,t+1} := b_{k,t}$
END
(∗ one-point crossover ∗)
FOR i := 1 TO m − 1 STEP 2 DO
BEGIN
IF Random[0,1] ≤ P_C THEN
BEGIN
pos := Random{1,...,n − 1};
FOR k := pos + 1 TO n DO
BEGIN
aux := b i,t+1 [k];
$b_{i,t+1}[k] := b_{i+1,t+1}[k]$
$b_{i+1,t+1}[k]$:= aux
END
END
END
(∗ mutation ∗)
FOR i := 1 TO m DO
FOR k := 1 TO n DO
IF Random[0,1] < P_M THEN
invert $b_{i,t+1}[k]$;
t := t + 1

Step 2: Filter the image with Gaussian filter σ,(*G(x,y)*)

$$G(x,y) = \frac{1}{\sqrt{2\pi x\sigma}} \times e^{-\frac{x^2}{2\sigma^2}}$$

Step 3: Implement the equation for stopping function:

$$K(x,y) = \frac{1}{1 + \left(\frac{\left\| \nabla (G(x,y) \times I(x,y)) \right\|}{k} \right)^{\alpha}}$$

Phase 2: Generating ψ, zeroth level set:

Step 1: Input segmented pupil image.
Step 2: Create pupil mask having radius greater than pupil radius.
Step 3: Generate ψ according to

$$\psi(x,y) = \begin{cases} 0, \; if\,(x,y) \quad is \quad on \quad the\,curve \\ < 0, if\,(x,y) \quad is \quad inside \; the\,curve \\ > 0. if\,(x,y) \quad is \quad outside\,the\,curve \end{cases}$$

Step 4: Display it on input eye image.

Phase 3: Perform segmentation:

Step 1: Maximum iterations = Input from user
Step 2: ε = Input from user
Step 3: Propagation =1(constant)
Step 4: Initialize ψ
Step 5: Evolve ψ according to discrete implementation equation,

$$\frac{\psi_{i,j}^{t+1} - \psi_{i,j}^{t}}{\Delta t} = -cK_{i,j}^{'} \left\| \nabla \psi^{t} \right\| - K_{i,j}^{'} (\varepsilon \kappa_{i,j}^{t} \left\| \nabla \psi^{t} \right\|) + \nabla \psi_{i,j}^{t} \cdot \nabla K_{i,j}^{t}$$

Step 6: Increment Δt according to Courant-Friedrichs-Lewy (CFL) condition.
Step 7: Check number of iterations and convergence.
Step 8: If number of iterations < maximum iterations or convergence is not reached Go back to step 6.
Step 9: Else Exit
Step10: Display final contour.

Phase 4: Estimation of radius

Step 1: Create mask by binarization of final contour.
Step 2: Calculate angle for all the values of final extracted contour.
Step 3: Check calculated angle if it is less than 182 and greater than 179.
Step 4: If yes then angle = 180°
Step 5: If no, Check calculated angle if it is less than or equal 212 and greater than 208.
Step 6: If yes then angle = 210°
Step 7: If no, Check calculated angle if it is less than or equal 152 and greater than 150.
Step 8: If yes then angle = 150°
Step 9: If no, Check calculated angle if it is less than or equal 32 and greater than30.
Step 10: If yes then angle = 30°
Step 11: If no, Check calculated angle if it is less than or equal 1 and greater than -1.
Step 12: If yes then angle = 0°
Step 13: If no, Check calculated angle is less than or equal -29 and greater than -31.
Step 14: If yes then angle = -30°
Step 15: Calculate Euclidean distance from pupil center using each angle.
Step 16: Take average of this 5 distances.
Step 17: Draw circle with this radius±20.

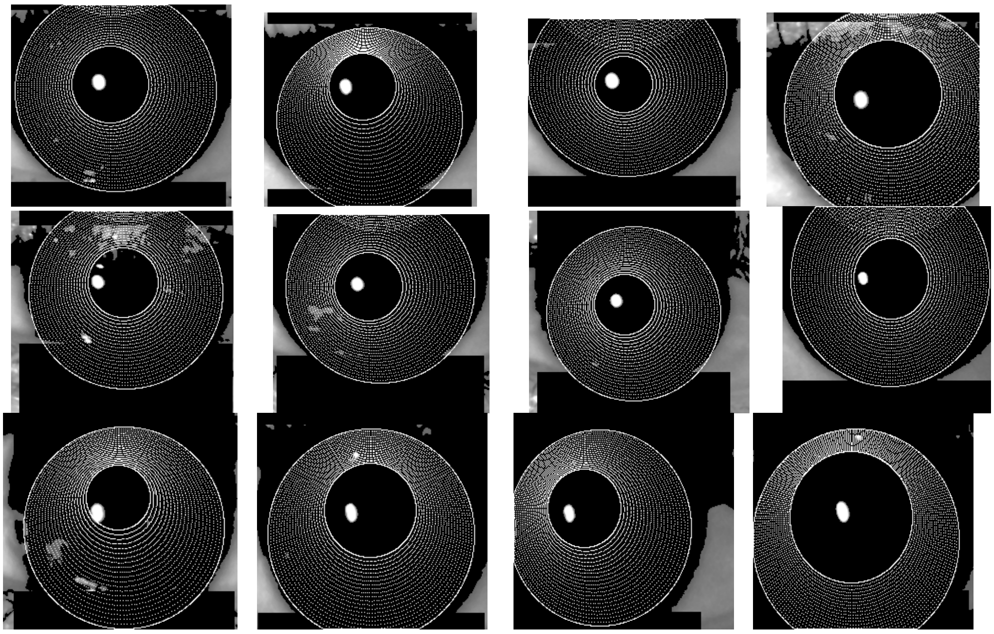


Figure 3.3: Segmented iris images

IV. RESULTS AND DISCUSSION

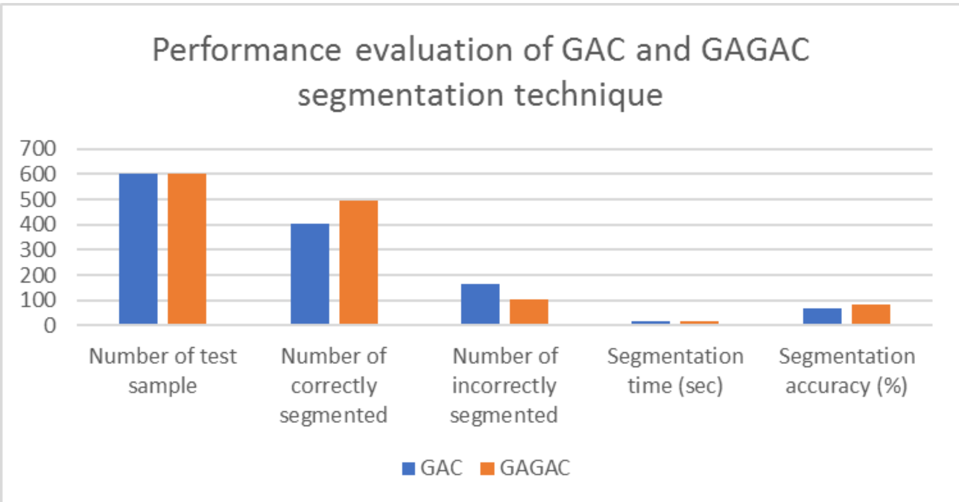
4.1 Results of the segmentation techniques

The results obtained in Table 4.1(a and b) depicts the performance of the segmentation techniques (GAC and GAGAC) based on the three ethnic groups. GAC

Table 4.1a: Performance evaluation of GAC and GAGAC segmentation technique

	GAC	GAGAC
Number of test sample	600	600
Number of correctly segmented	402	498
Number of incorrectly segmented	162	102
Segmentation time (sec)	18.18	14.49
Segmentation accuracy (%)	67	83

Table 4.1b: Performance evaluation of GAC and GAGAC segmentation technique



4.2 Discussion of the performance evaluation of the segmentation techniques (GAC and GAGAC)

The graph in Figure 4.1 (a and b) illustrated that GAGAC achieved a better performance compared to GAC in terms of segmentation time and accuracy. This improved performance displayed by GAGAC can be easily traced to the automatic parameter regularization performed on GAC parameters (which played an important role) using an adaptive strength of Genetic Algorithm (GA) by properly tunning them for an optimal value rather than the conventional GAC method where the regularization was done manually.

It was also observed that the two segmentation algorithms cannot achieve close to 100% accuracy as against the images acquired under strict and controlled environment. This is in line with the researches of Abhyankar et al. 2005, Vasts et al. 2008, Minal et al. 2012, Jillela and Ross, 2013 and Aworinde and Onifade, 2019. Most segmentation algorithm in literature use iris dataset taking under strict and controlled environment and when they get to real time performance, they may not be able to perform optimally. The improved performance displayed by GAGAC in terms of segmentation time and accuracy showed that if GAC parameters can be optimized, it has tendency to perform better than the conventional GAC segmentation technique.

The t-test result validates the fact that GAGAC outperformed the GAC segmentation technique in terms of accuracy and segmentation time. The t-test result validates the fact that GAGAC outperformed the GAC segmentation technique in terms of accuracy and segmentation time. In view of the analysis in this section, it can be inferred that the improvement made on GAC with GA achieved and improved performance significantly. The statistical analysis establishes the fact that the GAGAC segmentation technique archived significant improvement over GAC technique in terms of accuracy and segmentation time.

V. CONCLUSIONS

Based on the results of this study, it is concluded that the formulated segmentation algorithm (GAGAC) achieved improved segmentation in term of accuracy and time compares to conventional GAC. Also, the statistical analysis results carried out validated that GAGAC significantly increased the accuracy and reduced the segmentation time. This consequently implies that the optimization performed on GAC has positive impact on the efficiency of the developed iris-based ethnicity prediction system. It also indicated that the recorded higher accuracy for GAGAC was not due to sampling error but that there is statistically significant evidence that the optimized algorithms GAGAC performed better than the standard one GAC.

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