# A Segmentation Perspective of Non-Cooperative Iris Recognition

**K. Arthi, M. Rajeev Kumar**

***Abstract:** Iris Segmentation, an initial and vital stage of the iris recognition stage which directly affects the recognition accuracy. Especially, the non-cooperative environment that leads to contain many of the noise parameters in the captured image. Since the recognition accuracy of the iris biometrics system is extremely dependent on the proper iris segmentation, this paper is devoted to the segmentation perspective of the non-cooperative iris recognition system. The initial stage of the proposed method is started with applying a hybrid median filter algorithm to remove the possible noises and then a region-based level set algorithm is applied to overcome the identification of the concave property in the non-cooperative iris segmentation and enhanced Otsu's thresholding method is applied to the pupil segmentation. UBIRIS, a publicly available iris database for the non-cooperative situation, Version 1 and Version 2 is used for the implementation purpose. The accuracy of the segmentation result is achieved as 94.56 and 94.53 for the UBIRISv.1 and UBIRISv.2 respectively which show the proposed method as a better one.*

***Keywords:** Iris segmentation, Region-based level set algorithm, Otsu's thresholding method, Accuracy.*

## I. INTRODUCTION

Recent advancement of iris biometric attracts more and more researchers in the recent decade. Especially, the non-cooperative nature of the image acquisition helps to reduce criminal and other unwanted activities in both the business and residential environments.

Flom and Safir [17] obtained a patent for the iris recognition during 1987. According to their conclusion the probability of the existence of two similar irises are distinct persons at 1 in $10^{72}$. Though it was the kick-start for the iris recognition technique, the patent obtained by the authors is only a theoretical model. To bring out the very first commercial implementation model, Daugman proposed an integro-differential operator [15] by assuming both the iris and pupil as circular form. By using the parameters radius r, circle center coordinates $x_0$ and $y_0$ Daugman's integro-differential operator is defined as

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

where $\mathbf{I}(\mathbf{x},\mathbf{y})$ is the input iris image, $\mathbf{G_\sigma}(\mathbf{r})$ is the smoothing function.

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An alternative approach was proposed by Wildes [28] for iris localization that is depends on the intensity level of the input eye image. An edge detection algorithm has applied using the intensity value of the input image come behind by a

Circular Hough transform. The efficiency of his method is the dependency of threshold values on the edge map construction.

These two methods are the base for the initial iris recognition techniques that are followed by many of the earlier researchers [3] of this specific field and both the methods were provided better recognition rate for the input eye images with good quality. To obtain a better quality of eye images the cooperation of the individual is a mandate one. The situations in which the cooperation is not expectable from the individuals these two prime methods were degraded for the recognition accuracy.

Proenca [10] has introduced for the very first time a non-cooperative iris segmentation methodology which could give a better result for the heterogeneous and noisy iris image. When there are no enough sources to differentiate the sclera and iris region, the failure of the integro-differential operator is noticed by Proenca. To improve the image contrast and better result by overcoming the so-called drawback they applied two preprocessing optimizations, namely equalization, and Binarisation. To achieve an accurate and robust iris segmentation, Proenca evaluated the Tuceryan's methodology – a moment-based texture segmentation algorithm. In order to obtain the intermediate image from the classification of each pixels Proenca proposed a methodology that begins the process with image feature extraction followed by Fuzzy clustering. An edge map is being constructed using Canny edge detector on this intermediate image. Finally, the circular Hough Transform has been applied to get the expected segmented iris image. The feature extraction and clustering algorithm which was carried out by the authors are given as follows.

**Feature Extraction:** By performing several tests, Proenca concluded that the coordinates of the pixel position and their intensity are the more appropriate characteristics for the segmentation. They named this feature set as 'Pixel position + intensity'. The noise factors due to the eyelid may affect the posterior circumference identification stage.

**Clustering Algorithm:** Proenca evaluated the forthcoming four unsupervised clustering and classification algorithm; Kohonen's self-organizing maps/topological ordered maps, K-means, Fuzzy K-means, Expectation-maximization.

## II. RELATED WORKS

Vasta et al. [22] proposed a two-stage iris segmentation algorithms whereas the initial stage used the elliptical model to estimate the iris and pupil boundary of the eye image and the next stage they applied the modified Mumford-shah functional on the estimated boundaries of the first stage to identify the exact pupil and limbic boundary. CASIA V3, ICE 2005 and UBIRIS database are used to validate the effectiveness of their scheme.

An iris segmentation scheme is described by Samir Shah and Arun Ross [5] utilizing geodesic active contours to segment the iris from the input eye image. Their work iteratively elicits the iris texture. The accuracy of matching in iris recognition has been improved in this work. The CASIA V3.0 and WVU non-ideal iris dataset validate the efficiency of their algorithm. Mahboubeh Shamsi et al. [18] enhanced Daugman's circular Integro-differential operators to localize the iris boundaries. The speed and accuracy of the algorithm from a different point are evaluated by the circle contour sampling parameter. Zhaofeng He et al [37] worked on an accurate and fast iris segmentation. The eyelash and shadow detection is adopted in this algorithm based on the analysis of intensity distribution from different iris regions. Milena B.P Carneiro et al. [19] have explained a new iris segmentation method depends on the evolutionary algorithm. The Memetic algorithm is utilized to find the external iris boundary and the pupil boundary in an edge map.

To model the deformed pupil and iris boundary, the least square fitting of the ellipse method is implemented [34] vis-à-vis improving the overall efficiency of the non-cooperative iris segmentation algorithm form a video-based input image. The authors also incorporated a quality filter that adequately identifies a closed eye. A coarse-to-fine segmentation approach is also employed in this work. R.Chen et al. [27] investigated the iris segmentation into two aspects. Circular based model and Non-circular based model. They proposed a segmentation algorithm based on adaptive mean shit and merged active contour model which produced a better result for the non-cooperative situation. They tested their methods with the images which are taken under the near infra-red condition. A versatile iris segmentation algorithm is presented by P. Radu et al. [25]. This work focused on few of the concerns raised by unconstrained iris recognition. The authors concentrated on two sectors viz. (i) it can scope efficiently with both near-infrared and visible spectrum images. (ii) Their proposed algorithm increased accuracy. Przemyslow Strzelczyk [24] worked on the segmentation algorithm for both monochrome and color eye images. The voting mechanism is applied to select the iris region. Modified Hough transform is utilized to locate pupil boundaries.

A new method which segments the iris images from both image capturing environments (i.e near infrared and visible light) is framed by Chun-Wei Tan and Ajay Kumar [7]. This work deployed the multiple higher-order local pixel dependencies and involved robust classification of eye boundary pixel into iris or non-iris region. Also, the face and eye localization module is incorporated into this framework. An estimation of iris boundary is employed by Ruggero Donida Labati et al. [26]. In this work, the authors have furnished an algorithm to remove the reflection and occlusions. An analysis of iris segmentation is carried out by Z. Zainal Abidin et al. [38] using the state-of-the-art traditional methods viz. intergro-differential operator and circular Hough transform. The region-based level set algorithm is developed to overcome the drawback of identifying the nonconvex objects for the image segmentation applications by Vikram Appia and Anthony Yezzi [33]. They constructed a region-based energy minimization algorithm that addresses the problem of local minima.

An integrated algorithm is described vis-à-vis discriminating seven components of iris as well as the factors which affect the quality of eye image by identifying the periocular region [12]. All seven components taken for consideration in this work are captured in a single-shot. The solution for the uncontrolled environment and variations in subject pose and gaze are also addressed by Markov random filter. The author has further focused on indexing and retrieval method for degraded images. This research work was carried out particularly in the performance range for biometrics (hit rate>0.95). An algorithm designed by Abduljalil Radman et al. [2] is stared with finding the approximate location of the pupil center. Then, the localization of iris and pupil circle are carried out. Finally, a live-wire technique is implemented to extract the lower as well as upper eyelid boundaries. According to their implementation result, they have minimized the time which is required to perform the segmentation without affecting the segmentation accuracy and recognition rate. A circular Hough transform followed by the K-means clustering algorithm is used by Shaaban A. Sahmoung et al. [30] for iris segmentation. The identification of lower and upper eyelids also focused on this work. Andreas Uhl et al. [6] proposed a real-time iris segmentation based on weighted adoptive Hough transform and ellipsopolar transform.

A deep sparse filtering method is introduced by Kiran B.Raja et al. [16] for the input source from a smartphone-based visible wavelength environment. This work depends on the radius of the iris and the approximate measures of radius help to achieve the robust segmentation. Hence, this method is also based on the circular-based model. Instead of paying concentration only on localizing the pupil and limbic boundary, the attention is also given to identifying the eyelid and preprocessing stages of iris segmentation by Farmanullah Jan et al. [8]. A circu-differential accumulator (CDA) and para-differential accumulator (PDA) is used to identifying the limbic boundary and eyelid respectively. However, the CDA approach is more close to the Hough transform which indicates the proposed model as a circular-based one. Shu Zhang et al. [29] deployed eyelashes removal using field camera for iris recognition. This research work reconstructed the occluded iris patterns. The micro lens-based light field camera imaging system was also employed. An iris segmentation ground truth database is provided by Heinz Hofbauer et al. [9]. The prime motivation of this implementation is to evaluate the iris segmentation performance based on the ground truth of the database.

Additionally, this work provides the concept of identifying problematic cases in the segmentation algorithm.

A model selection technique is used to improve the color iris segmentation by Yang Hu et al. [35]. The main focus of this work is to improve the accuracy of the captured images from both static and mobile devices. Support Vector Machine (SVM) based classifier is utilized in this work which provides the selection decision. A total variation model is proposed to achieve an accurate segmentation framework by Zijing Zhao and A. kumar [39] under relaxed imaging constraints. Since this research is accomplished under both the imaging environment constraints viz. visible wavelength and near-infrared, it was well suited for forensics, identifying missing children and surveillance applications. The limbic boundaries of various input images are localized more accurately in this research.

Liu et al. [23] presented two models of convolutional networks by name HCNNs and MFCNs. These models identify iris pixels without handcrafted features or rules automatically. Further, attributes and classifiers are optimized. The first type of network takes input of the arbitrary size and the output is obtained without sliding window prediction. It was observed that the second type is more precise and robust than the first one.

The convolutional neural network (CNN) is used in this two-stage iris segmentation scheme. The dataset in this research is used from noisy challenge evaluation part-II and mobile iris challenge evaluation. This work carried out for the better iris recognition system where several noisy environments are considered. A non-circular iris normalization method is proposed by Abdullah MAM et al. [21] by considering the input images from both visible wavelengths and near-infrared environments. A new active contour force is applied for this purpose. Their main focus is to implement an iris segmentation for the non-ideal eye images and to identify the closed eye detection.

By considering the iris boundary and pupil as a circle, Yuvan-T Sung Chang [36] et al. implemented an iris circle calculation and pupil segmentation using the active contour model. According to their implementation they have identified the center position as well as the radius of the pupil. But in both the stages, they have assumed the pupil and iris as circle only.

In this paper, the segmentation perspective is provided prime concentration as the recognition accuracy is majorly dependent on this.

## III. METHODOLOGY AND RESULTS DISCUSSION

The initial step of the proposed non-cooperative iris segmentation is following one of the state-of-the-art image processing techniques called preprocessing. UBIRISv.1 and UBIRISv.2 iris dataset are used for our proposed research work. Initially, the color input eye image is provided as input which is converted to a grayscale one. Then, hybrid media filter is applied on this grayscale image. After this preprocessing step, Region-based level set (RBLS) algorithm is implemented to segment the iris boundary and then Particle Swarm Optimization is applied on it to achieve better iris segmentation. Finally, an automated Otsu's thresholding method is implemented for pupil segmentation. The details are provided in the subsequent sections in detail.

### A. Hybrid Median Filter

Hence the proposed research is dealing with the Non-Cooperative situation which expects the input image with several noise factors, there is a need for a powerful preprocessing method that removes the basic noise factors available in the input image. The nature and the workflow of the Hybrid media filter have given considerable acceptance to choose the algorithm as an initial stage of our proposed research. The hybrid version of the median filter shall be applied using the median filter with the following three constraints.

- Cross-mask
- x-mask
- results of cross-mask, x-mask and the element itself

The workflow of the Hybrid Media Filter is given in the following figure.

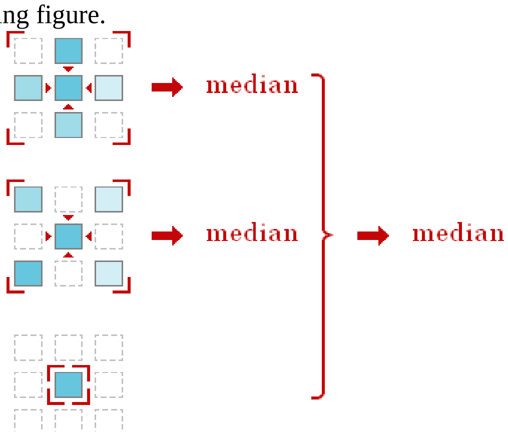



**Fig. 1.Workflow of Hybrid Media Filter**
**Fig. 2.**

According to the above workflow, the algorithm of the Hybrid Median Filter shall consist of the following steps.

**Stpe1:** Mark a cross-mask over the elements; pick the masked elements and order the elements.
**Step2:** Identify the middle element and pick the same.
**Step3:** Mark a x-mask over the elements; pick the masked elements and order the elements.
**Step4:** Repeat Step2.
**Step5:** Take the outcome of Step2, Step4 and element itself and order the elements.
**Step6:** Repeat Step2.

Edge treating is a common problem that will occur in all the mask filter algorithms. Whenever the elements are filled over the mask at the edge, few parts of the mask will always empty. To fill these gaps, the image should be extended. The image extension using the Hybrid Media Filter is always done by extending the image symmetrically that is depicted in the following figure.

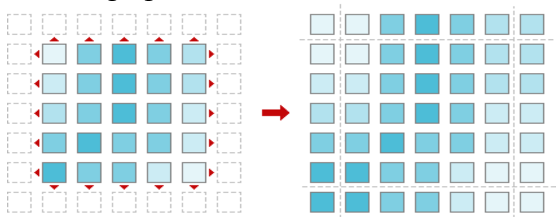
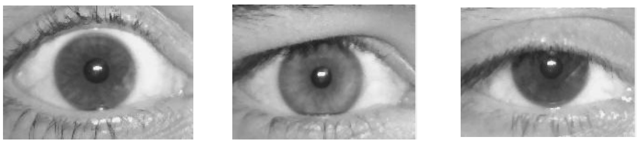


**Fig. 3.HMF Image Extension**



(a) (b) (c)

**Fig. 4.Effects of HMF for various input eye images**

### B. Iris Segmentation

Though various methods were discussed by several researchers for the snake active contour and geodesic active contour methods [33], the problem of identifying the nonconvex object using the active contour is a major concern and non-cooperative iris images always may lead to appear as non-convex like images. Since the region-based segmentation methods are considerably overcoming the problems of local minima, the proposed methodology uses the closed geodesic region-based energy by combing the saddle point (*S*) and shock curve (*C*) that indirectly mature the closed geodesic. Hence, the source and destination of the saddle points are to be the only two possibilities for the curve evaluation. The evaluation of the curve has been calculated until it reaches the minimum value for the region based energy. The outer layer of the iris will be formed based on the saddle point and shock curve. $S$ represents the saddle point on the curve C and it belongs to $S$ which creates a region of the vector field $\overrightarrow{\nabla u}$. Then, to characterize the region based on linear function $\varphi(x) = p$. By resolving,

$$\nabla\varphi . \nabla u = 0 \quad (2)$$

Now, assume a general category of region-based energies as,

$$E(C) = \int_{\Omega} f(x)dA \quad (3)$$

Then, the representation of gradient of $E(C)$ with respect to factor $p$ as per the line integral,

$$\nabla_p E = \int_c f.\nabla_p C.N.ds \quad (4)$$

where $s$ is the curve length factor and $N$ is the external normal to the curve $C$. Meanwhile, $f$ is a function of the factor $p$ and $C, \varphi(C,p) = p$

The gradient of this equation is represented as,

$$\nabla\varphi.\nabla_p C = 1 \Rightarrow \frac{\nabla\varphi}{\|\nabla\varphi\|}.\nabla_p C = \frac{1}{\|\nabla\varphi\|} \quad (5)$$

$$\nabla_p C.N = \frac{1}{\|\nabla\varphi\|} \quad (6)$$

Then, $C$ is inserted in the level set function, both the curve and external normal to the curve have the same outward normal $\|\nabla\varphi\|$. Therefore,

$$\nabla_p E = \int_c \frac{f}{\|\nabla\varphi\|} ds \quad (7)$$

The denominator factor of the line integral $\|\nabla\varphi\|$ differs from the influence of all the points on $C$. These points on the curve $C$ nearer to the saddle point which has a major influence on the integral than the points in the long distance. For the Chan-Vese energy equation, the function $f$ defined as follows,

$$f = 2(\mu - v)\{I - \frac{\mu+v}{2}\} \quad (8)$$

When disturbing the saddle point $S$ along the shock curve against $\nabla_p E$ (7), the line integral value monitors as how far the saddle point is disturbed along with the shock curve. As soon as the saddle point is distributed, a pair of open geodesics will return to the origin point from the current point which will form a closed geodesic. Now, this distributed saddle point will be considered as a new source which is at the new location. To re-compute $u$ from this new source, the selection of saddle points must satisfy the succeeding conditions.

- The related closed geodesic has lesser region-based energy than the energy of the closed geodesic attained previous to disquieting $S$
- Nearest to the prior selected point

To calculate the distance from the prior origin point, the collected cost from the earlier iteration is used as a parameter. As the saddle point is disturbed, the region-based energy for the closed geodesic diminish with each evolution of the curve. This process continues to prune the energy of the region.

### C. Optimization using PSO for iris segmentation

Optimization is performed to enhance the iris boundary more accurate from the identified one based on region-based level set. Particle Swarm Optimization (PSO) algorithm is utilized to minimize the energy of the gradient descent equation in a region-based level set segmentation algorithm. Excited by the social behavior of bird flocking, Kennedy and Eberhart [14] first introduced the PSO algorithm which is an evolutionary algorithm. This algorithm provides a population-based search scheme where particles change their states (positions) with time. PSO has several benefits such as easy, fast and less memory over other evolutionary algorithms. The previous experience and the set of particles which are closed to the particles are used to describe the direction of the particles.

Let, $x$ is the position or states of a particle and $v$ is its corresponding velocity in a multidimensional search space. The position or state of $ith$ particle is expressed as,

$$x_i = (x_{i1}, x_{i2}, x_{i3}, \dots, x_{id}) \quad (9)$$

where, d is the dimensional space.

The velocity of $i$th particle is expressed as follows,

$$v_i = (v_{i1}, v_{i2}, v_{i3}, \dots, v_{id}) \quad (10)$$

Now, the best among the previous position of the $ith$ particle is indicated as,

$$pbest_i = (pbest_{i1}, pbest_{i2}, pbest_{i3}, \dots, pbest_{id}) \quad (11)$$

The updated position and velocity of each particle is computed based on the present velocity in distance from $pbest_{id}$ to $gbest_{id}$.

$$v_{id}^{(t+1)} = w * v_{id}^{(t)} + c_1 * \left(pbest_{id} - x_{id}^{(t)}\right) + c_2 * gbest_{id} - x_{id}^{(t)} \quad (12)$$

Taking the availability of particles as $n$ in a group for the $t$ iterations and $m$ as the available members,

$$x_{id}^{(t+1)} = x_{id}^{(t)} + v_{id}^{(t+1)}, i = 1,2,3, \dots, n \ and \ d = 1,2,3, \dots, m \quad (13)$$

where $c_1$, $c_2$ is the stochastic acceleration terms and its range [0, 1], $w$ is the weight factor of inertia and $x_{id}^{(t)}$ is current position of the $i$th particle at iteration $t$. $v_{id}^{(t)}$ is velocity of the $i$th particle at iteration $t$, $v_{id}^{min} \le v_{id}^{(t)} \le v_{id}^{max}$ and $v^{max}$ measures the fitness of searching regions among the current and target position. The value of $v^{max}$ is large, then particles might fly previous optimal solutions and otherwise, particles search suitably outside local solutions.

Generally, the inertia weight $w$, expressed as,

$$w = w_{max} - \frac{(w_{max} - w_{min})}{t_{max}} \times t \qquad (14)$$

where, $w_{min}$ and $w_{max}$ is the beginning weight and final weight, $t$ is the number of repetition and $t_{max}$ is the maximum of it.

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Algorithm: Particle Swarm Optimization

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procedure
  initialize particles and position and velocity of each particle.
  while termination condition not met do
    Find local best ($pbest$) and global best ($gbest$) solution
    Update velocity of each particle, $v_{id}^{(t+1)}$
    Update position of each particle, $x_{id}^{(t+1)}$
  end while
  $gbest$ is the final solution
end procedure

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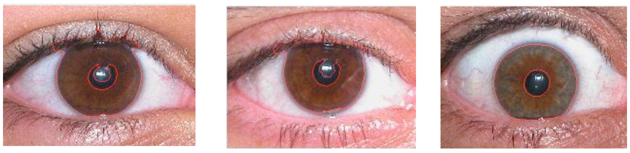
The decision of required number of iteration in the PSO algorithm is taken based on the convergence plot drawn using the calculation of best cost against each iteration. It was observed that after the fortieth iteration almost the best cost value got saturated and it does not reduce energy significantly. Hence, it is decided that PSO shall be applied for forty iterations.

Initially, the region-based level set algorithm itself is implemented to identify both the iris and the pupil boundary. Since the proposed segmentation research methodology focusses on overcoming the identification of concave like images, whenever the reflection noise occurs exactly at the pupil outer boundary and iris inner boundary the proposed method is suitable to identify the pupil region accurately. This constrain is also taken as the presented iris segmentation algorithm is effectively overcoming the identification of boundaries in the concave images. Fig. depicts the implementation results of region-based level set algorithm for both iris and pupil boundary. Though Fig. (c) shows the exact boundary identification of both the iris and pupil, the concave effects in Fig. (a) and (b) failed to identify the pupil boundary.



(a) (b) (c)

**Fig. 5.(a), (b) Incorrect pupil identification due to concave effect (c) Exact pupil identification**

### D. Pupil Segmentation

As the proposed methodology of iris segmentation is overcoming the problem of non-convex and local minima, it is felt during the implementation as not suitable for the pupil segmentation (due to reflection). There are several applications of image segmentation such as to measure tissue volume, locate tumors, treatment planning, computer-guided surgery, locate objects and object recognition, etc. In the proposed research, an enhanced Otsu's segmentation method is utilized to identify the pupil efficiently based on the image histogram and global thresholding method. Each pixel of the given image is mapped to the initially evaluated threshold value. The foreground and background of the iris image are decided based on the comparison between the initially computed threshold value and pixel value, above and below respectively. The histogram of an image that is obtained from the output of the region-based level set and gray-scale of the same are the base for the selection of an initial threshold value of this process. The algorithm for the enhanced Otsu's based segmentation is given as follows.

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**Algorithm:** Enhanced Otsu's based segmentation

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**Step1:** Select the input image ($I$)
**Step2:** Compute the histogram ($h$) of image ($I$)
**Step3:** Evaluate the initial threshold value, $T_1 = \frac{\sum(h * total\ shades)}{\sum h}$
**Step4:** Segment the image using $T_1$ which produce toe group of pixels foreground ($A_1$) and background ($A_2$)
**Step5:** Repeat the step-3 to attain the new threshold values for each class $(T_{A_1} \& T_{A_2})$
**Step6:** Calculate the new threshold value, $T = \frac{(T_{A_1} + T_{A_2})}{2}$

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Repeat Step 3 to Step 6 till the difference in T in consecutive iterations is not tends to zero

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The implementation of the enhanced Otsu's based segmentation for the pupil identification is applied on the output image of the region-based level set. The Fig. depicts the implementation results of the enhanced Otsu's method over the output of region-based level set algorithm.

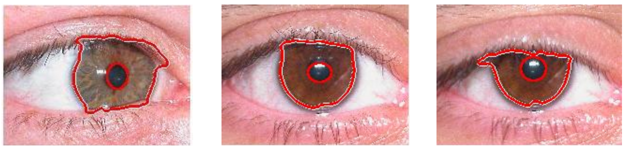

**Fig. 6.**Implementation samples of proposed methodology

To evaluate the performance of the proposed system, the accuracy parameter is taken for the account. We have taken the existing implementation of Chang et al. for the comparison with our proposed system which shows the achievement in terms of accuracy. The number of improper segmentation denoted with '*' in the Table-I is also included the 'no result' count used by the authors.

**Table- I: Performance comparison**

| | Dataset | No. of classes | No. of images successfully segmented | No. of improper segmented | Accuracy |
|---|---|---|---|---|---|
| Proposed Methodology | UBIRISv.1 | 201 | 1502 | 83 | 94.76 |
| | UBIRISv.2 | 206 | 3403 | 197 | 94.53 |
| Chang et al. | UBIRIS | - | 951 | 252* | 79.1 |

## IV. CONCLUSION

The implementation of non-cooperative iris segmentation is discussed in this paper. The identification of the Concave objects using the Active contour models is still the major concern among the researchers.

The geodesic Active Contour Region-based level set algorithm has proposed in this research to overcome this concern vis-à-vis identifying the iris region.

Further, the output of the region-based level set is applied to Particle Swarm Optimization to reduce energy gradient descent. Since the methodology used for iris segmentation is not suitable for the pupil segmentation, an enhanced Otsu's thresholding algorithm is used. The accuracy of this proposed two-stage segmentation methodology will also lead to achieving a better recognition rate in the succeeding modules of the iris recognition system.

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