A Novel and Robust Approach for Iris Segmentation

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ABSTRACT
Iris segmentation is almost the most challenging part in iris recognition. Several robust algorithms in the recognition part have been developed in literature yet. In this paper, we focus on an efficient approach for iris segmentation. The main purposes are to improve accuracy and to reduce computational time of iris localization. Briefly, this approach tries to explore regions of interests (ROI) among image regions and to localize iris from one or more remaining regions. ROI are the regions in which, the iris is most likely exit. An empirical binarization method for iris images is presented. Its aim is to preserve the iris region while removes background. A novel candidate selection is presented for extracting iris region among other image regions. For localizing the iris boundaries from the identified region, the Daugman' Integro operator is being used. It is obvious that iris localization from one or fewer number of regions is more accurate and faster than the whole detailed image. Moreover, a novel and very fast clustering algorithm is proposed. It is used to detect and remove some extra or rough details of image. The proposed approach is being tested on CASIA-IrisV2 dataset. The experiments show that the proposed approach yielded reliable regions of interest and provided accurate segmentation.

General Terms
Machine Learning: Clustering, Biometrics, Image Processing, Image segmentation.

Keywords
Iris recognition, iris localization, clustering, k-means, Integro operator, iris, optimization.

1. INTRODUCTION
Identification based on biometrics technologies, by increasing focus on security throughout the world, has been so far increasing. The biometrics can provide a natural means for reliable identification by examining the physical or behavioral traits of human beings [1]. According to uniqueness and stability of the biometrics during human's lifetime, it have has been utilized as a convenient method for the identification process for many years. The biometrics which is broadly being used in various applications includes fingerprint, retina and iris. Iris is a ring like chromatic texture between the black central pupil and white colored sclera in the human eye. Complex characteristics exist in iris pattern exhibit the iris as an important, convenient and non-invasive natural identification means. Especially in recent years, iris is more being utilized in identification systems. From a historical viewpoint, iris was proposed originally as a reliable biometrics in 1987 by L. Form [2]. Afterwards, Daugman [3] had utilized iris in 1993 for human identification process. His work was based on using 2-d Gabor transform. Since then, remarkable advances in biometrics application and theory has have been done. One of the major challenges in real time iris recognition systems is time complexity. Hybrid approaches which utilized various machine learning techniques and image processing solutions have been examined and proposed in literature. Their aim is to reduce overall computational time of algorithm and to empower more accuracy. Meanwhile, iris segmentation is almost the most challenging part of the iris recognition process. It is due to various noisy conditions which is usual in natural environment. For localizing and segmenting iris part of the eye, many of approaches have give aid from pupil. As the pupil is the darkest region in the eyes. So, it forms at least one of the darkest place in iris images. Therefore, it can help the recognition process. In many recognition systems, after some preprocessing, Hough transform along with canny edge detector are being utilized for creating edge map and finding circles with different diameters. Some others have utilized geometrical features, iris patterns and etc. On the other hand, these approaches could be converged to appropriate result in a fewer time steps. One solution is to perform some modification over input images using image characteristics. It is obvious that smaller input images e.g. smaller in size, smaller in feature or in regions could be faster processed rather than more complex ones. Most of applications try to remove or separate extra details from source images. Various innovative techniques can be utilized in this way. In this paper, it is tried to detect iris boundaries in an enhanced layout. So, exploring and separating regions of interest is our objectives. Various analyses in each part of current paper are proposed. An empirical binarization algorithm specific for iris images is presented. It tries to remove the background of iris image while preserves the iris area. A novel clustering algorithm for removing some regions of image is utilized. In this method, gray level intensity values are not considered at all. Instead, cluster density as well as cluster size is being considered. Afterwards, a new candidate selection method based on intensity and area is proposed. This algorithm extracts one or possibly more regions among candidate regions. Morphological operators are used to alleviate the effect of reflection (very bright spots) in the remaining regions. Finally, the Daugman's integro differential operator is being used to detect the boundaries of iris. This paper objective is not providing a complete iris recognition process. Hence, the detected boundary is the output of this paper. Variety of analyses has been done on every steps of the proposed approach. However, the main advantages of the proposed approach are reducing the time complexity and enhancing the accuracy of iris recognition process. It is obvious that, applying algorithm on a fewer number of regions, pixels or generally details, could yields more efficient or at least an equivalent

result. Briefly, main contributions presented in this paper are as follows.

I. An empirical binarization method for iris images,
II. A novel clustering algorithm inspired from conventional k-means clustering approach,
III. A special candidate selection from region of interests.

Each of which is described in details in its corresponding sections. The rest of paper is organized as follows: A brief description of some related papers is presented in section 2. The database, on which the experiments are conducted, is presented in section 3. The proposed algorithm is presented in section 4. In section 5, experimental results are represented. Various demonstrations from different parts are demonstrated there. Finally, conclusion and future work are provided in section 6.

2. PAPER REVIEW

There are several individual methods for iris segmentation and recognition in literature. In this section, a brief reference source from variety of papers is provided. Several methods and techniques are being investigated. These approaches could be classified in different manners. However, The authors in [4] appropriately classified those approaches as Phase-based, Texture-analysis based, Zero-Crosssing representation methods, intensity variations and approaches which use Independent Component Analysis. Such approaches as those represented by Daugman [5, 6] are categorized as phase-based, while the approaches presented in [7-9] are texture based approaches. The approach presented in [10] is mainly an intensity based method. This method acquires most of discriminating iris information through a 1-D intensity signal. In recent years, researchers have usually utilized hybrid methods to achieve better results. Faster methods and the more accurate results are recently more being considered. In [11] wavelet decomposition is applied on iris patterns. The authors have got aid from magnitude of coefficient to produce unique codes for recognition process. They have achieved an encouraging accuracy of 100% over ICE database. Integro differential operator is used to detect the boundary of pupil and iris by [12]. Then wavelet transform is utilized for analyzing and extracting iris patterns. Some authors also show that using only half portion of iris can be enough [13]. In their research, iris features are extracted and analyzed using Gabor Wavelet (GW), Local Binary Pattern (LBP) and Histogram of Oriented Gradient (HOG) methods. The best accuracy, over MMU iris database, is obtained using HOG method. It had an overall accuracy of 99.5% with an encouraging zero percent false accept rate (FAR) and 1.5 percent false reject rate (FRR). In other research, the textural and topological features are used to reduce the false rejection rates [14]. Furthermore, the authors have done more emphasize on the iris segmentation. An enhanced iris recognition system is proposed by Kaur [15]. They have tried to reduce overall computational time by an appropriate preprocessing procedure. For binarization, they have marked the image intensity values greater than apredefined threshold e.g. 70 to 1 and others to 0. This could not be promising while it is not adaptable with different lighting condition, especially when possible light surround some parts of iris. Furthermore, assume an iris image containing thick eyebrows and small iris region with some lights sharply radiated. In such the hard situation most of approaches could not be successful. A robust approach for iris recognition for non-ideal imaging conditions is proposed by Li et.al [16]. They used a 2-D Gabor filter for iris recognition. In their work, some noisy condition such as off-axis imaging, pose variation, image blurring, illumination, occlusion, specular highlights have tried to be considered. Another robust approach which is combined regional Gabor features with Adaboost learning algorithm, is given by [17] for noisy iris recognition. In the current paper, it is tried to reduce computational time while preserving accuracy for segmenting iris images.

3. IRIS DATABASE

The iris gray image database which is being utilized in this work is CASIA-IrisV2. The database is collected by the Chinese Academy of Sciences [18]. It includes two subsets. Each of which is taken with a different device. Each subset consists of 1200 iris images from 60 classes. The number of captured images for each eye is 20. The resolution of images is 640 × 480.

4. PROPOSED ALGORITHM

The proposed algorithm generally could be divided into four main steps. The first step is preprocessing. Its aim is to produce a semi binarized image using a novel empirical method. A new clustering algorithm is introduced in the second part. It is getting used to reduce the number of image regions. The third step is region extraction. Exploring connected components and extracting regions of interest are accomplished using a novel candidate selection approach. Finally, Iris boundaries are localized using Daugman’s integro differential operator in the fourth step. The algorithmic model is demonstrated in fig.1. Each step is described in detail in the following subsections.

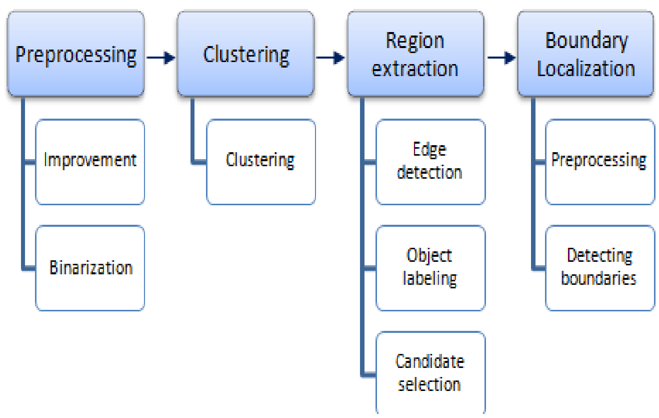

Figure 1. Proposed approach

4.1 Preprocessing

First, changing color space as well as some image enhancement is applied to the input image. Then an empirical binarization method is utilized to generate a semi binarized image which contains mostly the iris region. Each part is described in details as follows.

(a) (b) (c) (d) (e)

Figure 2. binarization methods: (a) Input image, (b) local binarization, (c) Otsu method, (d) Proposed method , (e) Semi binarized

4.1.1 Improvement

The input images are 3-dimentional vectors. For localizing irises in this paper, only gray version of images is necessary. A conventional equation (1) is used to convert RGB image into the corresponding gray instance.

$$G(r) = 0.2989 * Red + 0.5870 * Green + 0.1140 * Blue \quad (1)$$

This gray image will be used in the rest of work. In order to have more reliable localization of iris, various methods could be utilized. Most of iris recognition applications of iris recognition use some basic methods for reducing probable noises in the input image. One of the frequently used methods is histogram equalization which is fast and robust enough. The iris database being used in this work consists of variety of images which are taken in different illumination condition. Since, gray level intensity distribution of some iris images is so inappropriate; thus, using a method such as histogram equalization or similar ones for increasing image intensity dynamic range is crucial.

4.1.2 Binarization

The aim of this step briefly is to remove some details such as context from input image while preserving the image regions in which, the iris and subsequently the pupil are exists. In the next step, edge detection method shall be applied to the semi binarized image instead of the binary image. It means that after binarization, the non zero intensity value will be restored using corresponding original value. There are different approaches in literature for binarization and thresholding. In this paper, both Otsu method and local binarization have been investigated. In our previous work [19], local binarization is proposed and utilized as an enhancement for segmentation. In this work, input image is divided into 16 parts. Then Otsu method is applied separately for each one. In this application, none of these two methods could preserve image region of interests though. Several iris images, with various lighting conditions and different intensity distribution, have been investigated. Meanwhile, for all these various images, it is seen that the relation between the average of intensity values or a weighting value of that, could be promising. This thresholding can be appropriate if region of iris preserve. This relation is right for various iris images because:

I- The application will be looking for darkest pixels which at least contains pupil

II- Even though by this thresholding with respect to different lighting conditions, some portion of pupil and iris would be removed, but it is not important. Because a big region in which the iris is expected will be found. The intensity values inside this region of interest then will be restored by original enhanced image.

After investigating some values for weighing factor toward the average of intensity values, it is found that the equation (2) appropriately separates region of interests from context.

$$g(r) = 0.65 * m(f) \qquad (2)$$

where m is the average of intensity values of input image f and g is a semi binarized image. In fig.2, a comparison between these methods is demonstrated.

4.2 Clustering

General purpose of this step is to reduce number of image details in order to increase accuracy and decrease computational time of iris segmentation, respectively. In this work, the iris image will be analyzed with respect to region density and variance. Then, unimportant regions of image will be removed. The regions which are superfluous or extra and they do not affect the iris segmentation and recognition in future. This task could also have been done using linear analysis of image features or by applying filtering methods, but all of them suffer from high computational time complexity. The proposed algorithm time complexity is of $o(n)$; where n is the number of pixels in the image. The parameters of the algorithm, to increase speed and efficiency, are adjusted in a constraint and controlled way. To cluster the semi binarized image, the pixels with non zeros value will be separated. Then, centers distributes on the image surface using a predefined vector of centers. Afterward, pixels will be clustered based on their distance toward centers. Then, clusters with very low density value will be removed. Removing centers is the characteristics of this algorithm rather to K-means clustering algorithm. In fact, in this approach the number of centers i.e. K can be changed during the run of the algorithm. In the early iterations, removing centers and clusters with respect to the density of clusters occurs. Finally after some iteration, remaining centers are converged. Then, the variance of clusters with regard to correlation of their inside pixels is being estimated. On the other hand, in order to detect the probable singular cluster, the distance between cluster centers will be computed.

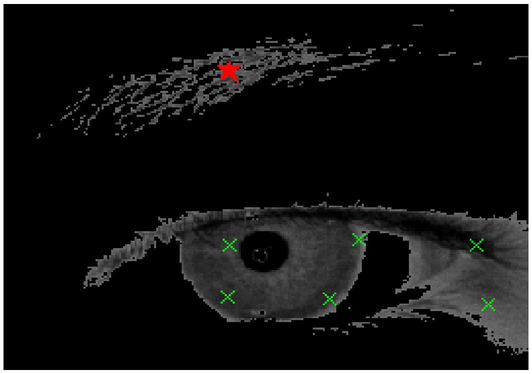

Figure 3. Singular Cluster: green checked are remaining clusters, red checked is a singular cluster

Then, probable singular cluster and the cluster with the highest variance will be removed. Some prerequisites are required and some fundamental concepts are behind this solution that this center-cluster removal in the early or in the final iteration could take place appropriately. The prerequisite is that the algorithm in current application works only on binary or semi binary images and the fundamental concepts are as follows:

I. If the number of centers is enough then the centers tend to converge toward the bigger regions. On the other hand, small regions could not contain iris region. Hence, low density clusters can be removed.

II. There is no problem if during removal process; some small parts of iris are removed. Because after estimating the region, its boundary box can be restored in future.

III. In the iris region, there is a high correlation between non zero value pixels. So, the clusters near iris region are of a lower variance. In this situation, assume that the number of clusters is enough i.e. more than two clusters, and there is a significant difference between variance of clusters. Then with regards to these conditions at least, the cluster with the highest variance could be removed. Note that, this removal can only occur after last iteration of algorithm.

IV. If the number of remaining centers after last iteration is enough then, the majority of centers are about biggest regions. Using this fact, singular clusters can be carefully removed. A clustered image is demonstrated in fig. 3. Majority of clusters are converged close to each other and singular cluster is easy to detect.

The Pseudo code of proposed clustering algorithm is demonstrated in Algorithm 1.

Algorithm 1: Extended K-Means

```
Input:
   P ← coordinates of non-zero intensity value pixel
   K ← number of initial centers
   Centers ← predefined centers
   Tag ← zero value vector with the same size as #P
   Count ← stores num of data points foreach cluster
Output:
   A reduced image
Begin
 While iteration < #iterations do
  Foreach p of P do
        // distance from each center
        Foreach c_i ϵ Centers do
            d(i) = ||p − c_i||
        End
        // assign the cluster number with min distance to Tag
        Tag(p) = argmin_i(d(i))
        // increase # of data point in its cluster
        Count (Tag (p)) ++;
  End
  // update centers
  Foreach cluster v do
     newCenters_v ← Average_v(containing_datapoints_v)
  End
  // difference vector of new centers with old ones
  Dff = ||newCenters − Centers||
  If Dff < threshold do
     Break
  End
  // remove or merge clusters
  If num of cluster > 5 do
   Foreach cluster v do
        Area(v) ← The area of v with respect to its bounding box
        Density(v) ← Area(v) / Count(v)
   End
   densityAverage ← Average(Density)
   // search for clusters for removing
   tobeRemoved ← argmin(Density < 0.6 × densityAverage)
   If tobeRemoved is not empty do
    // try to remove some clusters
      Foreach index of tobeRemoved do
        Remove ( cluster(index) with all data points)
      End
   Else
    // try to merge some clusters
   // average number of data points in each cluster
   countAverage ← sum ( Count) / (num of clusters)
    // search for index of smaller clusters
   tobeMerged ← argmin(Count < countAverage)
   Foreach index in tobeRemoved do
        Remove(Centers(index))
   End
  End //of if>5
 End //of while
End // of begin
```

Algorithm 1. Extended K-means Clustering

likely exists. To identify ROI first, the edge map of the iris image is obtained. Then, connected components are being explored. Finally, extracting iris region will be accomplished through a novel candidate selection approach. Each section is described as follows.

4.3.1 Edge detection

There are bunch of algorithms for edge detection. For this work, Sobel operator and Canny edge detection algorithm are being experimented. Sobel operator for this application does *not* generate a proper edge map of image and causes loss in accuracy. On the other side, Canny edge solution performs well and produce enough accurate and appropriate edge map.

4.3.2 Object labeling

Once the image edges are determined, connected components should be investigated. A connected component is a region which is surrounded by a boundary of interconnected pixels. On the other hand, connectivity between pixels is defined based on spatial adjacency and intensity values [20]. Among kinds of adjacencies, using 4 and 8 adjacency is most common. In this application, both of them have been investigated. But, using only 8-adjacency type yields appropriate results i.e. proper regions. Although, exploring connected objects could be done concurrently with computing area or other geometrical properties of regions; but, in this step for a better demonstration, a labeled matrix of connected component is commuted as output. In the labeled matrix, there is a label for each pixel that shows the region it belongs to. In the next step, these labels are being utilized to select proper regions.

4.3.3 Candidate selection

As the regions are obtained, it is time to select final regions of interest. On the other hand, it *is* obvious that iris region belongs to *big regions*. But to say that: "*it's the biggest region*", is controversial. Thus, toward selecting region of interests, image regions in several images regarding to the area, length-width ratio and intensity are being analyzed. Then, some relations are explored. It is tried for a better generalization, to consider a confidence interval when defining the conditions. These conditions are as follows:

I- The desired region must be among one of the four biggest regions,
II- Length of bounding box of the region is always shorter or at most equal to its width,
III- Average of intensity values of the region pixels satisfies equation (3).

$$0.7 * m(f) \leq m(h) \leq 1.3 * m(f) \qquad (3)$$

where m(f) is the average value of the intensity values of semi-binarized image while, m(h) is the average value of the extracted region. Although with regarding to equation (3), a large number of regions simply will be removed. But, as iris region belongs to big regions, investigating small regions is not necessary and so it is not considered. In this step first, the connected components with regard to the area will be descending sorted and four of the biggest regions will be extracted. Then, the bounding box, i.e. the smallest rectangle that can contain connected boundary, for each of the regions is being obtained. Subsequently, the width-length ratio and the average intensity value are being investigated for each of them. After all, one or more region will be selected as candidate or candidates for iris segmentation.

4.4 Boundary Localization

In this step, the obtained regions are being used for detecting iris boundaries. Beforehand, some noises such as reflection or inappropriate lighting conditions must be considered. In the following subsections, preprocessing and detecting iris boundaries are discussed in detail.

4.4.1 Preprocessing

During previous operations, some internal parts of the indentified regions might be removed. Therefore, the values of all pixels inside the bounding box of the region should be restored at first. Enhanced image acquired in part [] is used for restoration. Bright spots in some iris images causes variety of approaches fails to detect iris boundaries appropriately. These nearly white color spots are because of reflection or some lighting conditions. To fill these bright holes first, the morphological dilation algorithm is used with a disk-shaped structuring element of radius 4. Then, the morphological erosion method is utilized with a squared shape structuring element with radius of 1. Note that, some big spots might not completely be removed. But, the operations reduce their effects practically.

4.4.2 Detecting boundaries

There is variety of approaches for detecting iris boundaries in literature. Daugman's integro differential operator [21] is used to extract both inner and outer boundary of iris. It tries to find all possible circles in the obtained region. This integro operator, equation (4), acts based on the fact that the illumination difference between inside and outside pixels of the iris circle is maxima rather than other discovered circles.

$$\max(r, x_0, y_0) = \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r, x_0, y_0} \frac{I(x,y)}{2\pi r} ds \right| \qquad (4)$$

where, $I(x,y)$ is the gray level of image in the pixel (x,y), r represents the radius of the circle centered at $(x0, y0)$ and $*$ denotes convolution operation. Moreover, $G_\sigma(r)$ shows Gaussian smoothing filter. It is demonstrated in equation (5).

$$G_\sigma(r) = \frac{1}{2\pi r} exp^{-\left(\frac{(r-r_0)^2}{2\sigma^2}\right)} \qquad (5)$$

where G_σ represents radial Gaussian function with center r0 and standard deviation σ. The integro operator applies iteratively while the amount of smoothing by Gaussian function successively reduced in order to achieve a precise localization.

5. EXPERIMENTAL RESULTS

The methods described in section 4 are applied to several iris images of the database of CASIA-IrisV2. The new empirical binarization method for iris images is compared with other methods and demonstrated previously in fig. 1.

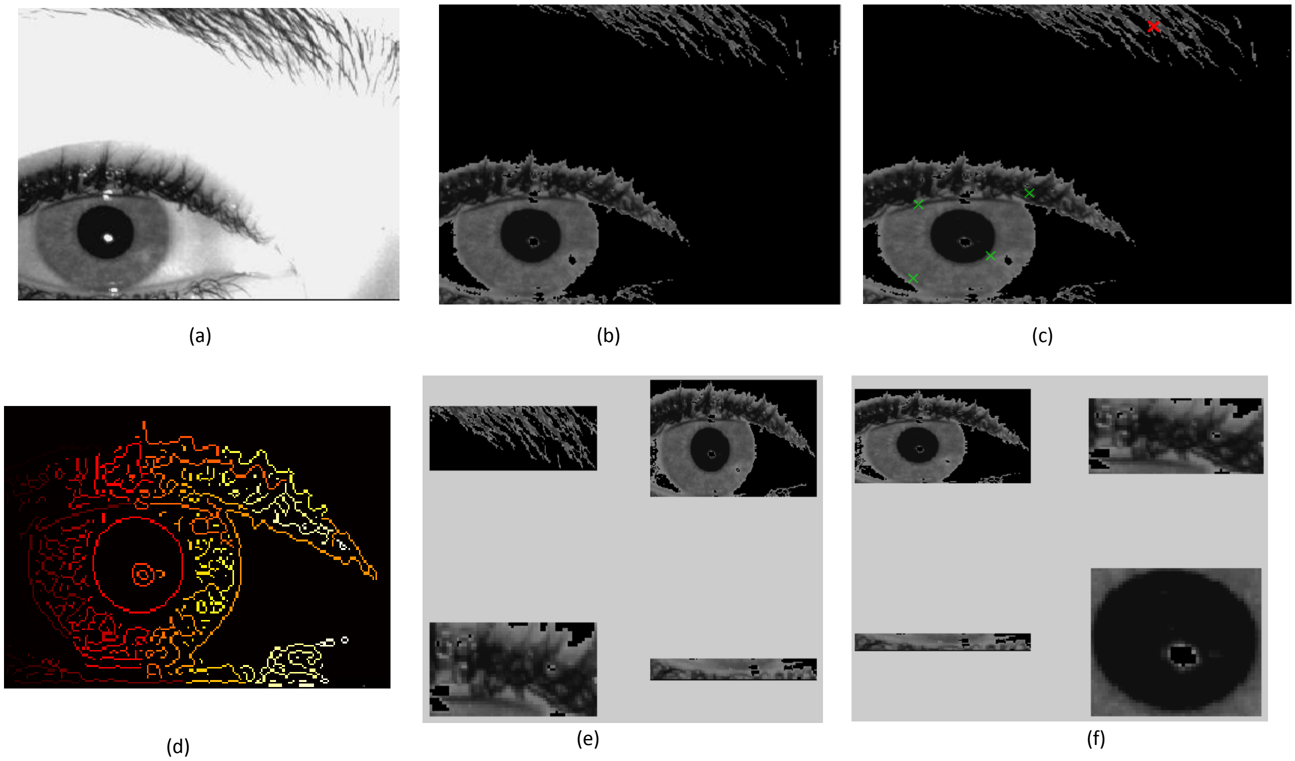

Figure 4. Region Extraction: (a) Input image, (b) semi binarized, (c) clustered image: green marked are remaining cluster, red marked is checked for removing, (d) labeled edge map, (e) four biggest region before clustering, (f) four biggest region

Herein, the proposed clustering algorithm as well as its procedure and its effect is more being demonstrated. In fig.4, proposed region extraction is exhibited. It is being compared with the one that the clustering is not applied. Both, part (e) and part (f) are applied on the semi binarized image of part (b). Proposed clustering algorithm is applied and selected the eyebrow cluster in part(c) for removing. After the red marked cluster removed, edge detection and implied object labeling using 8-connected component is utilized and exhibited in part(d). In part (e), four of the biggest regions is separated. As it shoes, the biggest region is the eyebrow in top left. But, in part (f) the biggest region is iris area while other regions could be removed more easily. With respect to the proposed candidate selection, the regions in the bottom left and bottom right will be removed due to their width-length ratio. The second big region is also being removed because of the condition presented in equation (3).

The clustering algorithms parameters have been adjusted to have only 12 iterations and 16 centers ($K = 16$). On the other hand, the algorithm is allowed to have at least five centers at last. The algorithm performs very fast and converges rapidly. In Fig.5, the steps in which the proposed clustering algorithm reduces the details of input image is presented. First, centers distributes on the surface of the semi binarized image (part (b)). Then, centers will be merged and converged progressively. During the progress, one of the centers with lowest density is selected and marked with red color (part (c)) to be removed. Since, the remaining clusters are of a near density as well as the close number of containing data points, so no change in the number of clusters would be made. Finally, six clusters are remained. Although, the density of the red marked cluster in part (e) is more than some of them, but as it is a singular cluster, it is selected for removing.

6. CONCLUSION AND FUTURE WORK

In this paper, an efficient approach for iris segmentation is proposed. The main purposes of the presented algorithms are enhancing accuracy and reducing computational time. the main idea was to extract more proper region among image regions. Clearly, working with a fewer number of regions or generally an image with fewer details causes reduction in computational time. In the other hand, the segmentation accuracy would be increased especially when some rough regions are removed. An empirical binarization specifically for iris images represented. It preserved the iris region while removes most of background areas. Then, a novel clustering algorithm had been utilized. The algorithm accomplishes very fast with complexity of $\mathbf{O}(\mathbf{n})$; where, $\boldsymbol{n}$ is the number of pixels with non zero values in semi binarized image. The clustering algorithm was utilized to remove some extra and rough details of iris image. Afterwards, connected components with 8-connectivity was being explored. Then, extracting regions of interest with respect to area, length-width ratio and intensity values was accomplished. Variety of algorithms could have been utilized for detecting iris boundaries in the remaining region. Herein, after some morphological operation for image enhancement, the Daugman's integro differential operator was being employed. Several demonstrations for various parts of presented algorithm were exhibited in experimental results. As

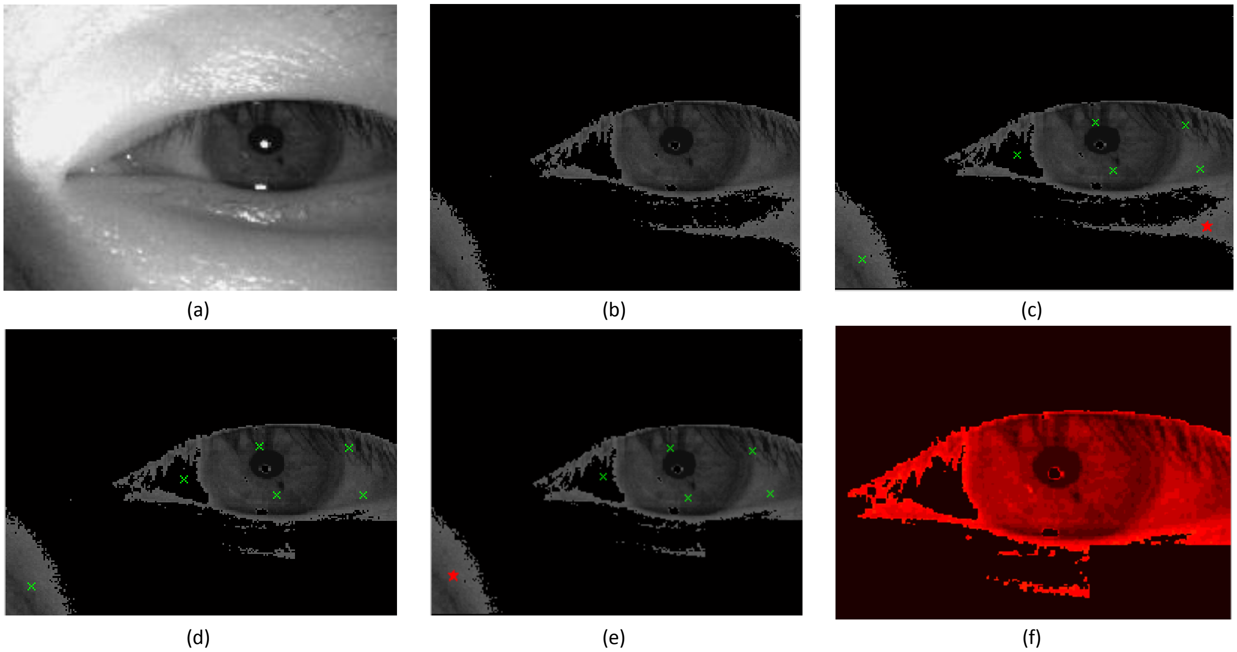

Figure 5. Clustering: (a) Input image, (b) semi binarized, (c) after some iteration: green marked are centers of remaining clusters, red marked is selected for removing, (d) remaining clusters after the end of clustering, (e) singular cluster red color marked, (f) labeled after total image reduction

future works, the clustering algorithm can be extended to localize precisely the iris region. Besides, analyzing other image characteristics such as intensity distribution or the luminance component in YUV color space could also improve the results. As a matter of fact, more robust analysis yields more adaptive algorithms in natural environment.

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