Implementation of Geodesic Active Contour Approach to Localize Anomaly Marker on Iris Surface

Mohamad Faizal Ab Jabal¹, Mohd Shafry Mohd Rahim², Mustafa Man³, Illiasaak Ahmad⁴

¹Department of Computer Science, Faculty of Computer and Mathematical Sciences, University Technology MARA Johor Branch, Pasir Gudang Campus, Johor, Malaysia; ¹UTM ViCubeLab Research Group, Faculty of Computing, University Technology Malaysia, Johor, Malaysia; ²School of Informatics and Applied Mathematics, University Malaysia Terengganu, Kuala Terengganu, Terengganu, Malaysia; ³Department of Computer Science, Faculty of Computer and Mathematical Sciences, University Technology MARA Kedah Branch, Merbok Campus, Kedah, Malaysia;

Introduction

Iris recognition system can be applied to various applications. The used of iris recognition system in medical field, known as Ophthalmology, has been well accepted by health practitioners. Ophthalmology is the area of study that focuses on the health care of the iris, retina and eyes (Preethi and Jayanthi, 2014). The existence of anomaly markers on the iris surface, as shown in Fig. 1.1, may indicate the possibility of eye diseases (Preethi and Jayanthi, 2014). However, due to the dynamic form of the anomaly marker on the iris surface make it very difficult to be localized automatically using iris recognition system.

Fig. 1.2 shows challenges in iris segmentation, which can be categorized into two: common and rare issues. The common issue such as occlusion, motion-blurred, and off-angled are well study by various researchers (Jillela and Ross, 2013) particularly in biometric authentication systems. However, the outlier issue is a rare case in authentication system, but it is a common situation can be found in ophthalmology field (Preethi and Jayanthi, 2014). The outlier situation can be defined as the acquired eye image with abnormalities in the shape of the iris as shown in Fig. 1.1. These abnormalities may interrupt the recognition process of the iris (Jillela and Ross, 2013). Based on the outlier definition and considering the anomaly marker description, this paper has extended the outlier definition to the iris image that contains the anomaly marker on the iris surface, which is also possible to interrupt the recognition process (Mustafa Man et al., 2016).

Abstract: The aim of this paper is to study the effectiveness of geodesic active contour approach to localize the anomaly marker on iris surface. Anomaly marker is an abnormal marker that appears on the iris surface, which may lead to eye diseases. The multi appearance, scattered location and dynamic shape of the anomaly marker on the iris surface make them very difficult to detect using automatic localization method. Therefore, this paper presents the preliminary works that observe the efficiency and accuracy of geodesic active contour approach to automatically detect the anomaly marker on iris surface. Miles database and “lu_wei_feb_2006” dataset are used in this study. The results of the conducted experiment show that geodesic active contour approach able to correctly and accurately detect up to 77% and 90% of the anomaly marker in Miles database and “lu_wei_feb_2006” dataset, respectively.

Keywords: Anomaly marker, Iris localization,
The main purpose of localizing the anomaly marker on the iris surface is to detect abnormality symptom or activity on the iris surface that may indicate a possibility of eye diseases. The dynamic forms of the anomaly marker make it rather hard to be detected automatically. This study applied the geodesic active contour approach to detect and localize the anomaly marker. The main idea to use this approach is to evaluate the efficiency and accuracy of geodesic active contour in localizing the multi-objects in images. The multi-objects in this study are referred to anomaly markers. Based on the method proposed by Sandhu, the author applied the geodesic active contour approach to localize the Kaposi Sarcoma in medical MRI image (Sandhu et al., 2008). For education and research purposes the author shared the program source code online and is used in this study. Few modifications of the program were made to suit the objective of this study.

The structure of the paper is organized as follows. Presentation on the related work will be in literature review section. Methodology section provides an overview of the dataset used for the experiment. The method of the geodesic active contour approach also been explained in these section. The localization performance is reported in testing section. Conclusion section concludes the paper and the future work.

**Literature Review**

**Multi-object Image Segmentation Approaches**

Table 2.1 shows several prominent multi-object image segmentation approaches targeted for medical purposes. It can be said that these approaches are highly accurate in localizing the region of interest of multi-object in an image. Nevertheless, the processing time to perform the detection is still unacceptable. For instance Chen et al. (2012) and Kéchichian et al. (2011) took around 300 sec. and 720 sec. to correctly detect the region of interest in an image, respectively. It was active contour approach that stands out in terms of processing time as proposed by Lucas et al. (2012) and Sandhu et al. (2008). They not only managed to accurately localize region of interest but also speed up the processing time.

**Table 2.1. Multi-object localization approaches**

<table>
<thead>
<tr>
<th>Localization Approach</th>
<th>*Accuracy Rate</th>
<th>Processing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clustering and graph cuts (Kéchichian et al., 2011; Beichel et al., 2012; Vela et al., 2012)</td>
<td>High</td>
<td>~ 720 sec. (Kéchichian et al., 2011)</td>
</tr>
<tr>
<td>Graph cuts and oriented active appearance models (Chen et al., 2012)</td>
<td>High</td>
<td>~ 300 sec.</td>
</tr>
<tr>
<td>Mesh-coupling algorithm (Kainmueller and Dagmar, 2015)</td>
<td><strong>NA</strong></td>
<td><strong>NA</strong></td>
</tr>
<tr>
<td>Visual patch (Li et al., 2015)</td>
<td>High</td>
<td><strong>NA</strong></td>
</tr>
<tr>
<td>Active contour (Gao et al., 2011)</td>
<td>High</td>
<td>~ 45 sec.</td>
</tr>
<tr>
<td>Geometric active contour with energy model (Sandhu et al., 2008)</td>
<td>High</td>
<td><strong>NA</strong></td>
</tr>
<tr>
<td>Geodesic Active Contours (Lucas et al., 2012)</td>
<td>High</td>
<td>~ &lt; 10 sec.</td>
</tr>
</tbody>
</table>

*Accuracy Rate is based on pixel accuracy: High (0.7 – 1.0), Medium (0.3 – 0.69), Low (< 0.5).
**NA**: Not Available

**Iris Boundary Segmentation Approaches**

Back in 1994 Daugman have introduced Integro-differential operator to automate the localization of the iris region in eye images (Jillela and Ross, 2013). However, the approach does not consider the eyelashes and eyelids. This allows other researchers to contribute into the field. Wildes proposed circular Hough transform to accurately segment the iris region on the eye image (Jillela and Ross, 2013). Later, with a slight modification of the circular Hough transform algorithm Masek employed the revised Hough transform algorithm to extract the iris region. Result from Masek experiment shown that the improved algorithm was accurately extracted iris region with the accuracy of 98.6% (Jillela and Ross, 2013). Although the result has shown an improvement towards the approach, the reliability of the eye images used in that experiment has been questions. Bowyer in 2013 stated the eye image from CASIA database (CASIA version 1) is not reliable to be used as a primary dataset because the image has been edited to get a perfect circle on the pupil and iris (Bowyer et al., 2013). Moreover, the pupil color has been modified to become darker than a normal pupil. It is to increase the color intensity for a reason to ease the pupil region detection during segmentation process. Therefore, every significant approach that been developed and tested based on the CASIA database will achieve high accuracy rate. But when the approach was tested against with a
secondary dataset the outcome shows a negative result as presented in Fig. 2.1.

![Segmentation](image)

**Fig. 2.1.** Inaccurate segmentation on iris boundary

Based on available documented literatures, Jillela and Ross had reported there are various iris segmentation approaches have been proposed to deal with the non-ideal eye image such as off-angled, occlusion, and blurry motion situation as summarizes in Table 2.2. However, it is very rare to find documented publications on outlier’s situation. This is due to the fact that the outlier’s situation is not a main concern in the iris-based authentication system when compared to healthcare related systems like ophthalmology.

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shah and Ross</td>
<td>Geodesic active contour</td>
</tr>
<tr>
<td>Roy et al.</td>
<td>Variational level sets</td>
</tr>
<tr>
<td>Daugman</td>
<td>Fourier-based approximation</td>
</tr>
<tr>
<td>Schuckers et al.</td>
<td>Active shape models</td>
</tr>
<tr>
<td>Pundlik et al.</td>
<td>Graph cuts</td>
</tr>
<tr>
<td>Zuo and Schmid</td>
<td>Ellipse fitting</td>
</tr>
<tr>
<td>He et al.</td>
<td>Pulling and pushing model</td>
</tr>
<tr>
<td>Du et al.</td>
<td>Scale invariants feature transform</td>
</tr>
<tr>
<td>Masek</td>
<td>Circular Hough transform</td>
</tr>
<tr>
<td>Wildes; Malek; Ma</td>
<td>Edge detection and Hough transform</td>
</tr>
<tr>
<td>and Kovesi; Ma et</td>
<td></td>
</tr>
<tr>
<td>al.; Lim et al.;</td>
<td></td>
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<tr>
<td>Huang et al.</td>
<td></td>
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<tr>
<td>Yuan et al.</td>
<td></td>
</tr>
<tr>
<td>Huang et al.</td>
<td>Phase congruency and Hough transform</td>
</tr>
</tbody>
</table>

**Table 2.2.** Iris Boundary Segmentation Approaches (Jillela and Ross, 2013).

Methodology

**Dataset**

Fig. 3.1 shows the sample of the iris image that was used in this study. It is known as Miles Research database prepared by Miles Research Company. The images have been acquired by using PV320C. Size of the image is 1749 x 1184 pixels in 256 dpi resolutions. The images have been stored in Joint Photographic Experts Group (jpeg) file format. The color space is 24-bits RGB (Johnson, 1984; Miles Research, 2013). The image has been filtered manually into two categories, which are normal iris image and anomaly iris image. Since the objective of this work is to localize the anomaly marker on the iris surface only the anomaly category was used.

![Miles Research iris database](image)

**Fig. 3.1.** Miles Research iris database: a) Normal iris image. b) An iris image contains anomaly marker on the iris surface

In addition, another dataset named “lu_wei_feb_2006” was also used in order to have different type of images and ultimately study the efficiency geodesic active contour approach. This dataset was prepared by Russell et al., (2008) from Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology (MIT), Cambridge, USA. Unfortunately, there is no detail information regarding the equipment used or standard operating procedure (S.O.P) on how the images were acquired.

![Anomaly marker on the iris surface](image)

**Fig. 3.2.** “lu_wei_feb_2006” dataset. a) Single object. b) Multi-object

**Pre-processing**

The first phase in this work is to localize the iris position from the eye image. Circular Hough transforms was deployed, where the iris is the ROI in this work. The approach is used because the ability of the approach to approximate the center and radius coordinates of the pupil and iris regions when the numbers of points that fall on the parameter are known (Rai and Yadav, 2014). The process starts with the image conversion from RGB to gray scale image. Then Canny edge detection is applied in order to find the edges. This process can be presented as arithmetical equation as shown in (1) and (2),

\[ x = x_c + r \cdot \cos \theta \]  \hspace{1cm} (1)
\[ y = y_c + r \cdot \sin \theta \]  \hspace{1cm} (2)
where

\[ r \] is a radius and \( x_c, y_c \) is a center coordinate of the circle.\n
While \( \theta \) is a degree of the angle when it sweeps through the full 360° range, the points \((x,y)\) will trace the boundary of the circle. Then for all edge points \((x_i,y_i)\), \(i=1,2,...n\) Hough transform is applied in order to localize the pupil and iris region. The arithmetic equivalent of Hough transform is shown in (3) and (4),

\[
H(x_c,y_c,r) = \sum_{i=1}^{n} h(x_i,y_i,x_c,y_c,r)
\]

\[
h(x_i,y_i,x_c,y_c,r) = \begin{cases} 1, & \text{if } g(x_i,y_i,x_c,y_c,r) = 0 \\ 0, & \text{otherwise} \end{cases}
\]

where

\[ g(x_i,y_i,x_c,y_c,r) = (x_i^2 - x_c^2) + (y_i^2 - y_c^2) - r^2 \]. The three coordinates \((x_c,y_c,r)\) for which \(H(x_c,y_c,r)\) is highest will be the coordinate of the center and radius of the circle. Fig 3.3 shows the output of the process.

Fig. 3.3. Pupil and iris region localization

On the other hand, it is not necessary for “lu_wei_feb_2006” dataset to be extracted into the ROI form, because the obtained image is ready for localization process. However, the images need to go through the gray scale and masking processes in the pre-processing phase.

Object Localization Process

The second phase of this work was to localize the anomaly marker on the extracted ROI images using geodesic active contour approach as shown in Fig. 3.4. A modified version of, Sandhu (Sandhu et al., 2008) source code was used. However, slight modifications to the program have been made in order to make the program reliable with our images. The first modification was took place on the image acquisition, so the program is able to receive the visible light and high resolution of the image instead of gray scale image and 32 x 32 resolution of image. Next modification is on the iteration, where the original is 800 and has been changed to 500 loops.

The first step is to assume \( f \) (ROI image) consists of the object and background. In this case the object is the anomaly marker and the background is the iris surface. The process started by calculating the similarity metrics in the image to portray the object or the foreground. Hence level set algorithm has been used to proceed with the process. Let the curve \( C \) represent a zero-level set to a signed distance function \( \phi : \mathbb{R}^2 \to \mathbb{R} \), and if \( \phi < 0 \) it will be indicated the inside of \( C \), otherwise it is outside of the \( C \). This indication is presenting the object or background in the ROI image, where the inside of the curve \( C \) matched that means the object, else is a background. A more thorough discussion of the equation can be found in Sandhu (Sandhu et al., 2008).

![Fig. 3.4. Object localization method (Adapted from Sandhu et al., 2008)](image)

Next, the values of the metrics were used to threshold the image where the curve \( C \) on the ROI image is a boundary that separating between the object and the background. Finally, the boundary detection program is executed to draw the outline of the boundary to show the localize object found in the ROI as presented in Fig. 3.5 and Fig. 3.6.

![Fig. 3.5. Example of localization result of a single object; a) from Sadhu et al. (2008) dataset; b) from lu_wei_feb_2006” dataset](image)
Testing

Setup

The experiment was conducted based on the following hardware and software specifications; 2.3GHz processor, 8 GB of memory with speed of 1333MHz, Intel HD graphics 3000 512MB, OS X version 10.11 as a platform, MATLAB R2014B. Non-iris images from “lu_wei_feb_2006” and Sadhu et al. (2008) were used in the first experiment. In the second experiment Miles’s iris dataset was applied to the test program. In both experiments the test program must perform single and multi-object localization.

Result and Validation

Fig. 3.5 and 3.6 shows the result of the first experiment that has been conducted using non-iris images. It can be clearly seen that Sandhu’s approach had successfully localized a single object. It also correctly detects the multi-object in the image. This study believes that Sandhu’s approach should able to localize the anomaly marker on the iris surface. To prove our claim, we fed in iris images from Miles database to the test program.

Fig. 4.1 presents the sample of correct iris localization results while Fig. 4.2 presents the sample of incorrect localization results of Miles database. In general, it can be said that the objects was successfully localized. Although the accuracy rate achieved is only around 77% (see Table 4.1), it proves that Sandhu’s approach can be applied to localize anomaly marker on iris surface. There are few factors that contribute to low accuracy rate.

<table>
<thead>
<tr>
<th>Database/dataset</th>
<th>Percentage (%)</th>
<th>Processing Time (Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles Database</td>
<td>77%</td>
<td>4.7</td>
</tr>
<tr>
<td>“lu_wei_feb_2006” dataset</td>
<td>89%</td>
<td>1.3</td>
</tr>
</tbody>
</table>

First, after further investigation to the images in Miles database we found that the boundary detection process was influence by the color and illumination intensity of the anomaly markers or objects. Second, the incorrect threshold values have been produced in order to create the mask. We also found out that the anomaly marker is slightly difficult to detect when the color of the marker is nearly the same as the color of the iris surface. A darker color of anomaly markers is desirable for this purpose. Furthermore, light reflection on the pupil area and iris surface also influence the boundary detection process.

The average of the execution time for the program to run all the processes for every single image from Miles database is between 4-7 minutes. While for the “lu_wei_feb_2006” dataset its take around 1-3 minutes. The slight difference on the execution time is because of the resolution size of the images. Moreover the iteration for the boundary detection has been set around 500 loops. Therefore the execution time for Miles database is slower than the “lu_wei_feb_2006” dataset.

Based on the experiment, the generated output from the execution program for the boundary detection in order to localize the anomaly marker was fairly performed but in certain cases it was imprecise as shown in Fig. 4.3. Overall, the geodesic active contour has a potential and reliable to be applied towards the anomaly marker localization on the iris surface or multi-objects localization in the image.
There are, however, several issues that must be addressed in which we believed contribute to low execution performance and accuracy rate. First, the used of boundary feature detection to localize objects by seeking the similarity metrics on the image is not suitable to be applied on the iris image. It is because the iris surface is not a plain surface as images from “lu_wei_feb_2006” dataset. The iris surface consists of the iris various patterns and colors. If the existence of the anomaly marker on the iris surface had a similar shape or pattern, and color with the iris surface, then the approach is easy to miscalculate the similarity metrics, when the process of calculating is acquired the values or data from the grey scale image. It is because the program will produce a wrong direction to localize objects that the program to localize the anomaly marker.

Although the image from “lu_wei_feb_2006” dataset was obtained with the plain background, still the approach is able to miscalculate the similarity metrics and produced imprecise localization output. The reason is the illumination of the light or reflection was generated high intensity of the color on the object. Therefore, when the image was converted into the grey scale, it was found that the spot with the high intensity on the object is presented as white. It will give a different meaning to the program when the grey scale image is convert into the binary image, where the white color will be represent as value 1. At the same time the value of the object that should be localized will be represent as 0. Hence the boundary line will be drawn on the objects that represent 0 in the image. As a result, imprecise localization to the object will be produced.

Second, the execution time for each image from both databases to be processed could be considered as slow processing time. The calculation process influenced the resolution size of the image during seeking the similarity metrics. The program will search for the similarity point all around the image. Next the higher resolution size of the image, the slower execution time will be produced from the program to generate the localization output.

Although the result from the conducted experiment does not show the robust achievement regarding the detection and localization, but it is enough to prove that the geodesic active contour approach is reliable to be applied for anomaly marker localization on the iris surface.

Most publications regarding the geodesic active contour approach focused on localizing big objects in the image compared with the anomaly marker on the iris surface, which is smaller in size, exhibits various patterns and colors of the object to be detected. Therefore in detecting and localizing the smaller objects on the various patterns and colors background is much challenging compared with the ordinary conducted lab experiment with the lab ideal image or database set.

Conclusion

This paper presented the application of geodesic active contour approach to detect and localize the anomaly marker on iris surface. Our experiments have shown that it can be applied not only to localize multiple objects, but also with different sizes. A modification of Sandhu’s (Sandhu et al., 2008) geodesic active contour approach has also shown an improvement in localization accuracy rate.

Future Work

Further research can be conducted on the approach in which it can be applied to localize micro objects on the various backgrounds in the image. Moreover, it is also possible to use geodesic active contour with current boundary feature algorithm to improve the localization method. As a result of this marriage the localization will be more precise compare and increase the localization accuracy rate.

Acknowledgement

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References


