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Particle Swarm Optimization-Based Thresholding for Corneal Segmentation in Pterygium Detection

[1]Siti Raihanah Abdani, [1]W. Mimi Diyana W. Zaki, [1]Aini Hussain and [2]Mohamad Hanif Md. Saad
[1]Smart Engineering System Research Group (SESRG), Department of Electrical, Electronic and Systems Engineering,
[2]Department of Mechanical and Materials Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia

Abstract: Pterygium tends to affect those who are exposed to prolonged uv radiation in which Asian people are more susceptible to develop such condition. Thus, a computerized method that can automatically detect pterygium is greatly needed and is being proposed using image processing approach. The main focuses of this researchers is corneal segmentation of eye region in the Anterior Segment Photographed Images (ASPI). A heuristic approach based on Particle Swarm Optimization (PSO) thresholding is explored to segment the corneal to further improve the segmentation rate of non-ideal images that contain pterygium condition. To obtain the corneal after applying PSO, the three steps thresholding method is used based on frame differencing between multi color channels (HSV). Brazil Pterygium (BP) database is used to represent the pterygium condition while UBIRIS.V_1, UBIRIS.V_2 and Miles databases are used to represent the normal eye condition. Both pterygium and normal ASPIs have been tested rigorously to validate the robustness of the proposed algorithm. The results showed that BP have the highest accuracy (94%) while UBIRIS.V_1 have the highest accuracy (93.2%) for the non pterygium database. In conclusion, it shows that the proposed method is mostly suitable for application in Asian countries in which there is increasing trend of pterygium cases.

Key words: Pterygium, ASPI, particle swarm optimization, frame, accuracy

INTRODUCTION

Pterygium is an eye condition that usually affects people who is working in outdoor environment for a prolonged period oftime such as farmers, fishermen and contractors (Hamid *et al*., 2014; Karai and Horiguchi, 1984). Pterygium is a condition where fibro vascular tissue has growth on to the corneal region which can affect vision quality if it is left untreated, mainly due to astigmatism (Kampitak, 2003). Apart from that, pterygium also has been closely associated with the other UV related diseases such as skin cancer (Yu *et al*., 2014). Thus, it is important to detect the condition early so that mitigation treatment can be administered to prevent further complication.

Pterygium can easily be detected by using conventional camera where the tissues can be clearly seen on the Anterior Segment Photographed Image (ASPI). The fibro vascular tissues have reddish or yellowish appearance with various thickness. There have been many reports that of ASPI usage in diagnosing variouseye diseases by using Digital Image Processing (DIP) techniques (Ramanathan and Balaraman, 2007; Nasution and Kusuma, 2009). As such, we would like to aim for a development of computerized pterygium screening tools to facilitate the ophthalmologist in screening the pterygium early by using DIP approach.

This research proposesan image processing technique to segment corneal in order to extract the pterygium tissue based on ASPI. As mentioned earlier, the fibro vascular tissue will encroach to the corneal region if the pterygium is prevalence. Usually, iris segmentation is used for the iris recognition purposes, but in our case, an imperfect iris is a good indicator to the existence on pterygium tissue.

Iris is a region in the eyes with pigmented surface where it is contain unique biometric information for each individual (Strzelczyk, 2010). It can be used as security

Corresponding Author: Siti Raihanah Abdani, Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia

validation similar to the fingerprint. In order to segment the iris, most of the DIP algorithms approach the issue through pupil segmentation first. Pupil is the dark region that is located in the middle of the eye that functions as the gate to let the light into the eye. Since, our research is not focusing on the iris recognition, we emphasize on corneal region segmentation in the ASPI of the eye region. Corneal region is the area that covers up the iris region and the pupil region (Tomidokoro *et al*., 2000). Basically, our cornel segmentation is to differentiate the corneal limbus from the eye sclera. In pterygium cases, this border (corneal limbus and the eye sclera) will be affected and thus suitable to be implemented in the detection process.

One of the main novelties of this study is to investigate corneal segmentation based on Particle Swarm Optimization (PSO) applied to the ASPI of the cropped eye region. This research is done with the intention to develop full automatic pterygium detection that can be used to screen pterygium cases early, especially for the rural areas.

Particle Swarm Optimization (PSO) for image segmentation: Image segmentation is defined as the process of dividing a digital image into a specific regions or objects. This process is important for medical image analysis as it requires a lot extraction process of object of interest such as lesion segmentation which extracts the region of interest that contains the specified condition. However, there are many issues that need to be overcome in order to develop an accurate segmentation module. For the ASPI image of the eye region, the usual non-ideal images have always been the issue for the segmentation module. Some examples of the issues that need to be solvedare the illumination problem, reflection problem and unconstrained environment during the image acquisition.

Generally, segmentation module involves the division of image's pixels into different classes. Pixels that have similar features will be grouped together. However, the distribution of the pixels with lack of information poses a challenge in grouping them and this is where the PSO algorithm is used to overcome such problem.

Basic principle of particle swarm optimization: Kennedy and Eberhart (1995) have proposed a bio inspired algorithm which is closely related to swarm intelligence concept, inspired by study on social behavior of birds in a flock. The particles are initialized randomly and searching process is done on the entire search space to find the most optimal solution. This can be done by using the neighbor particles which is the local best (individual best solution) and the neighborhood best. Also, in every step of the procedure, particles will be updated and the particles will find the new location of the search space for the success particle. The success particle gained is formulated based on the (Ghamisi *et al*., 2012, 2014) by using predefined fitness function. The basic stepsand parameters of the PSO algorithm are described in Table 1.

Table 1: PSO algorithm parameters

Parameters	Description
Particles	Candidate solution
Velocity vectors	Position change rate
Position vectors	Location of the movement of the particles
Fitness	The particle success
Local best	Individual best solution
Neighborhood best	Optimal particle search movement within the neighbourhood
Global best	Globally optimized particle search movement

Basic procedure of PSO algorithm:

Initialize the swarm (Initialize particles, velocity vectors, position vectors, neighborhood best, global best)
Loop:
For all the particles
Evaluate the fitness of each particle
Update the local best, neighborhood best and global best
Update the velocity vector and the position vector
End
Termination procedure is basedon the termination condition

Applications of PSO in image segmentation: There are many applications that have implemented PSO algorithm, in which DIP is one of the fields that have investigated extensively on this algorithm. PSO has been used and proven to be suitable for segmenting things into classes. Furthermore, PSO algorithm have been improved through hybridization with other automatic segmentation techniques such as thresholding (Zheng *et al*., 2009).

Thresholding method is the most popular method to extract the segmented region. It is proven to be an effective method, especially on the gray scale image such as Magnetic Resonance Image (MRI) and Computer Tomography (CT) images. Thus, an optimal threshold value is important to extract the object of interest optimally from the gray scale image. An entropy based threshold is also one of the popular methods that have been used to find the optimal threshold (Zheng *et al*., 2009).

Zheng *et al*. (2009) have proposed a PSO-based method to improve their gray scale image segmentation. In their research, entropy of the image is obtained from 2D grayscale image. However, this entropy calculation requires a lot of computational time. By integrating with PSO algorithm, the computation time is lower while the accuracy of the segmentation has been improved. The PSO algorithm optimizes the gray

Table 2: Information on databases of ASPI of eye region

Name of database	Brazil Pterygium (BP) (Rafael and Mesguita, 2012)	$UBIRIS.V_1$ (Proença and Alexandre, 2005)	$UBIRIS.V_2$ (Hugo *et al.*, 2010)	Miles database (Miles, 2015)
Type of database	Pterygium only	Iris recognition database (assumed as normal database)	Iris recognition database (assumed as normal database)	Assumed as non-pterygium database. From observation, it was assumed that all the eye are not normal eye which is have other eye condition
No. of database	59 images	1877 images 2 sessions of photography	11102 images 2 sessions of photography	
Eye angles	Frontal and non frontal	All frontal angle	Frontal and non-frontal	All frontal database
Image size	Varies	300×400	300×400	1747×1180
Bit Depth	Varies	24	24	24
Horizontal resolution	Varies	300 dpi	72 dpi	256 dpi
Vertical resolution	Varies	300 dpi	72 dpi	256 dpi

histogram and indirectly improves the maximum entropy threshold value. They have concluded that the 2D maximum entropy method by considering both gray information and spatial information reseaches the best with a lesser computational time.

A similar research have been done by Molka where they have taken advantage of the 2D entropy thresholding method in the standard images. Zhang and Liu (2006) also have applied this entropy-based optimization method on the underwater images. Usually, underwater image will have a very low contrast due to low surrounding illumination and the assimilation of the water. This low contrast issue will affect the quality of edge detection and image segmentation. By applying PSO, it optimizes the entropy value to produce better segmentation result with lesser computational cost.

Cai-Hong *et al*. (2012) integrated the PSO algorithm for image segmentation by combining ISODATA algorithm. ISODATA algorithm is one of unsupervised algorithms for image classification purpose. It has been popularly used in remote sensing images to segment the land covers based on their land usage. Their research has shown a promising result where the segmented regions were extracted effectively.

Slimene and Zagrouba (2011) have also proposed a novel kernel clustering method by combining Support Vector Clustering (SVC) algorithm with PSO which is called as PSO-SVDD. This approach is designed in order to utilize the disadvantages of the SVC cluster algorithm effectiveness. This method was validated by using Berkeley dataset where it managedto optimally find the cluster region without knowing the number of regions required for the image clustering.

Hongpo *et al.* (2010) have applied the PSO hybrid techniquein high resolution sonar images. Their algorithm combined PSO with Fuzzy Cluster Method (FCM) where PSO will first produce the clustering information and the output will be acclimatized to the FCM. This method has been compared with the traditional FCM where it produced more reliable segmentation results.

All hybridization of PSO with other techniques has shown that by incorporating PSO with artificial intelligence approach, segmentation accuracy will be improved. An improved image segmentation method could indirectly produce a better image analysis. In this study, we investigate the potential of integrating PSO algorithm with thresholding for corneal segmentation of ASPI for pterygium detection (Table 2).

MATERIALS AND METHODS

This study explains the experimental setup of the PSO algorithm corneal segmentation that has been integrated with the proposed thresholding method reported in our previous research (Abdani *et al*., 2015a). Figure 1 shows the block diagram of the proposed method.

Four datasets are used to validate the proposed PSO-thresholding corneal segmentation. All the datasets consist of ASPI of eye region captured in RGB format. One of databases is specialized on pterygium cases (Brazil Pterygium (BP) while the others is specialized on non-pterygium eye database. For the validation purpose, 30 images from each database are randomly selected to investigate the proposed methodology.

The groundtruth images have been manually generated by using Windows Paint where the edges of the corneal that are not affected by the pterygium tissue were outlined carefully by trained expert. Then, by using MATLAB, the region of interestsare changed into white pixels (R = 255 G = 255 B = 255) while the background pixels are set to black (zero) to form a binary ground truth image (Table 2).

The ASPI is segmented by using color information using basic PSO approach based on the algorithm that has been explained in Table 1. Before that, the images need to go through some pre-processing. Enhancement technique is applied to enhance the image by using our previous image enhancement method where an adaptive sigmoid enhancement has been applied. In the PSO color segmentation, we experiments withvarious segmentation level ρ to find the most appropriate value for the ASPI images. After that, the frame differencing from our previous research is applied to segment the corneal images. The output of the segmentationis passed to the post processing module where the morphological operation is applied to smooth the binary images. Then, the largest blob will be retained and assumed to be the corneal of the images (region of interest-ROI). The ROI is then compared with the ground truth that was manually traced by trained expert to evaluate the segmentation performance.

RESULTS AND DISCUSSION

Pterygium is an eye condition where a non-cancerous tissue encroaching onto the corneal region. Usually in the iris segmentation, the inner and outer boundaries of the iris (pupil and limbus) need to be differentiated in order to extract the iris area only. Then, this iris segmentation will be further used for iris image analysis such as iris recognition. For pterygium case, the tissue can be observed in the ASPI images easily where the encroachment can affect the appearance of corneal limbus

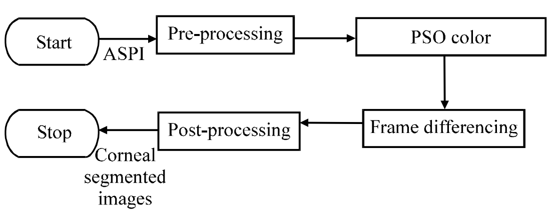

Fig. 1: Proposed experimental setup by integrating the PSO color segmentation algorithm

which directly altered the shape of eye corneal. In this case, only corneal region (iris and pupil) needs to be segmented on the corneal limbus (border of corneal and sclera region).

Pterygium tissue observed from ASPI can appear as reddish or yellowish color tissue. The fibro vascular tissue can have variety of thickness that poses difficulty to the segmentation algorithm. So, a heuristic segmentation method is needed to overcome this variation. PSO algorithm has shown some promising results in the previous works that has been summarized in the previous study. Other than ASPI of pterygium cases, we also have compared the corneal segmentation results with the other eye database (non-pterygium cases). Figure 2 portrayed the corneal segmentation by using PSO color segmentation.

Then, the output of PSO will be fed to the frame differencing module as used in Abdani *et al.* (2015b) for final segmentation. The performance of the corneal segmentation is evaluated by using accuracy, specificity and sensitivity. The results show that Brazil Pterygium database have the most high accuracy with 94% while UBIRIS.V_1 have the highest specificity with 99.61%. For the normal database, UBIRIS.V_1 obtains the highest accuracy with 93.20%. This is because of the data acquisition of the database itself. UBIRIS.V_1 images have been captured in more ideal environment while the other two databases have been captured in less ideal environment where the illumination and reflection are not constant. However, for BP database, the data acquisition environment is also not ideal where various focus length and background illumination can be observed. Another important fact that should be considered is the location of the iris itself. Most if the iris in BP database is located in the middle of the eye region while the other databases are not exactly centered. Other than that, colour of the iris also affects the segmentation accuracy since European eyes has closer colour intensity with sclera region. It has been proven that the brownish iris is easier to be segmented since the colour contrast is higher. Thus, we can conclude that this algorithm is more suitable for Asian

Fig. 2: PSO color segmentation

Table 3: ASPI of eye region databases

Name of database	Brazil Pterygium (BP) (%)	UBIRIS.V_1 (%)	UBIRIS.V_2 (%)	Miles (%)
Sensitivity	79.21	69.87	89.15	59.72
Specificity	98.33	99.61	90.00	96.74
Accuracy	94.00	93.20	89.92	82.14

peoples where they have higher risk to be affected by pterygium. Table 3 summarizes the results of performance evaluation for all four databases.

CONCLUSION

Segmentation results for BP database showed the highest accuracy whereas for non-pterygium database, it was the UBIRIS.V_1 that has the highest accuracy. As such, it can be concluded that the proposed method based on PSO for corneal segmentation is suitable to be adopted for detecting pterygium amongst Asian communities. This is because non-brown iris will most likely has a weak segmentation output dueto limitation in threshold method. For the future research, the algorithm will be modified to be more robust for non-brown iris color people by integrating color constancy algorithm (Zulkifley *et al*., 2012).

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