Spot Filtering Adaptive Thresholding (SFAT) Method for Iris Pigment Spots Segmentation Approach

Mustafa Man

School of Informatics and Applied Mathematics, University Malaysia Terengganu, Kuala Terengganu, Terengganu, Malaysia

mustafaman@umt.edu.my

Mohamad Faizal Ab Jabal*

Digital Graphic & Media (DiGM) Research Group, Faculty of Computer and Mathematical Sciences, University Technology MARA Johor Branch, Pasir Gudang Campus, Johor, Malaysia

m.faizal@johor.uitm.edu.my

Wan Nural Jawahir Wan Yussof

School of Informatics and Applied Mathematics, University Malaysia Terengganu, Kuala Terengganu, Terengganu, Malaysia

wannurwy@umt.edu.my

Suhardi Hamid

Faculty of Computer and Mathematical Sciences, University Technology MARA Kedah Branch, Sungai Petani Campus, Kedah, Malaysia

suhardi@kedah.uitm.edu.my

Mohd Shafry Mohd Rahim

TM ViCubeLab Research Group, Faculty of Computing, University Technology Malaysia, Johor, Malaysia

shafry@utm.my

ABSTRACT

Automation on iris pigment spots detection is an open issue that was highlighted by one of the previous researcher in 2016. The purpose is to detect the iris pigment spots in order to make an early prognosis regarding the eye cancer that was cause by the iris nevi. The nevi also known as a pigment spots on the iris surface, which is one of the features on the iris surface. Hence, this paper has proposed Spot Filtering Adaptive Thresholding (SFAT) method in order to solve the highlighted issue. SFAT method has introduced a new thresholding intensity values and enhancement towards the colour detection algorithm.

Then, the testing has been conducted on the Miles research digital iris images. The result achieved from the testing is 37.02% of the accuracy on the segmentation of the iris pigment spots on the iris surface. Moreover, increment 35.08% of accuracy on the iris pigment spots detection process compared with the previous method. The finding from the validation process towards SFAT method is the reliability of the method, which is was concerned on the complexity of the method implementation is low and the processing time of the method is less than 10 seconds in average compared with the previous method. In addition, the contribution from this study is in the medical imaging and image processing field of research.

Key Words: Colour Feature; Filtering Approach; Thresholding Method; Pigment Spot Segmentation.

INTRODUCTION

Medical imaging is a well-known research area. Image and signal processing is a technology typically applied in order to develop a medical imaging system.

Ophthalmology is a medical area that concern on the health care of the iris, retina and eyes according to Man, M., Jabal, M.F.A., Rahim, M.S.M. (2012), Edwards, M. (2016), and Edwards, M., Cha, D., Krithika, S., Johnson, M., Parra, E.J. (2016). Iris has a stable structure and unique pattern despite biological twins, as suggested by Lai, C. L. and Chiu, C. L. (2010) and Preethi, D.M.D. and Jayanthi, V.E. (2014). The existence of the pigment spots on the iris surface is a normal environment in the Ophthalmology field. In the biological understanding, the existence of the pigment spots also can be considered as one of the iris feature (Edwards, M., 2016). However, the increment of the pigment spots size on the iris surface may indicate to the eye cancer, which is known as Uveal Melanoma (UM) according to Man, M., Jabal, M.F.A., Rahim, M.S.M. (2012), Edwards, M. (2016), and Edwards, M., Cha, D., Krithika, S., Johnson, M., Parra, E.J. (2016). Furthermore, there are multiple Epidemiologic reports that contribute to understanding the risk factors of UM, but the results remain inconsistent (Weis, E., Shah, C.P., Lajous, M., Sheilds, J.A., Sheilds, C.L., 2009).

Although many segmentation approaches been proposed earlier, still there are limitations to segment the pigment spots accurately. Several preliminary experiments have been conducted in order to investigate the cause of the pigment spots unable to be segmented accurately. The finding from the investigation can be categories into two factors. First factor is because of the pigment spots feature (Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012). Second factor is because the limitation of the filtering approach used in the system.

The feature of the pigment spots is a reason the segmentation result is inaccurate. Dynamic form of the pigment spots pose difficulty for the segmentation process to perform accurately. Dynamic form has been defined as being varied on the shape, the position on the iris surface, the size and the number of the existence on the iris surface (Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012). In other words, there is no stable features can be used to segment the pigment spots on the iris surface. Besides, it is much easier to segment the objects in the image when all features regarding the object are recognised.

In addition, the existence of pigment spots on the iris surface has increased the difficulty level for segmentation process because the background colour of the pigment spots is not a plain colour. Colour of the iris surface is a background of the pigment spots. The environment of the image can be classified as unconducive environment of image. In this situation, the correct filtering approach must be employed in order to separate the background colour and pigment spots before further process can be conducted. However, the existing filtering approaches have a limitation in order to perform the process. Hence, the limitation of the filtering approaches has contributed as a second factor of the inaccuracy segmentation result.

Therefore, the direction of this paper is to propose a new filtering approach, namely Spot Filtering Adaptive Thresholding (SFAT) method. The main purpose proposing SFAT method is to improve the accuracy issue in the iris pigment spots segmentation. Furthermore, in this paper also contains the feature of the iris pigment spots, which is not been published previously. The performance of the proposed approach also been discussed in this paper and the accuracy percentage been recorded.

After knowing the factors of inaccurate segmentation result, this paper has conducted an investigation to recognise a pigment spots feature in order to assist the segmentation process. Extensive discussion has been conducted in Literature Review section. Moreover, several relevant filtering approaches also been discussed in the same section. Proceeding with the investigation, this paper has proposed a new filtering approach, namely Spot Filtering Adaptive Thresholding (SFAT) method and further elaboration has been held in the Methodology section. Next, the comparative study and result validation has been discussed in the Experiment section and the Result and Validation section separately. Finally, the works finding, summary and future work are compiled in the Conclusion section.

LITERATURE REVIEW

The discussion in this section is categorised into two sections. The first section will extensively discuss regarding the features. The second section will discuss about the relevant filtering approaches that have been proposed earlier by other researchers.

A. Iris and Iris Pigment Spots Feature

Iris is a part of eye component can be access by others from the outside without doing any surgery or x-ray. Iris consists of the stable structure and texture since year born until death, according to Lai, C. L. and Chiu, C. L. (2010) and Preethi, D.M.D. and Jayanthi, V.E. (2014). Moreover, iris texture is complex and unique from one to another despite biological twins.

In the biological field, iris features are contained of freckles, furrows, stripes, and coronas, as suggested by Bastys, A., Kranauskas, J., Krüger, V. (2013) and Sidhartha, E., (2014). On the other hands, Edwards, M., Cha, D., Krithika, S., Johnson, M., Parra, E.J. (2016) had defined the iris features contains of fuchs' crypts, wolfflin nodules, pigment spots, contraction furrows, and conjunctival melanosis.

However, from the biometric field, iris features are used for recognition purposes. The common features used are vector feature, boundary feature, binary feature and edges feature (Bastys, A., Kranauskas, J., Krüger, V., 2013; Adegoke, B.O., Omidiora, E.O., Falohun, S.A., Ojo, J.A., 2013; Bowyer, K.W, Hollingsworth, K.P, Flynn, P.J., 2013; Jillela, R., Ross, A.A., 2013; Man, M., Jabal, M.F.A., Rahim, M.S.M, Hamid, S., Yussof, W.N.J.W.; 2018). Vector feature is a construct features to recognise the iris. There are two important properties in constructing the vector feature, which are saliency and suitability (Odinokikh, G., Fartukov, A., Korobkin, M., Yoo, J., 2017). Binary feature is known as iris code and it is a common feature used in commercial iris recognition system (Nalla, P. R. and Kumar, A., 2017). The method works when the real iris code is combined with the synthetic binary texture or real value pattern to provide a transform enrolment or transform query used in biometric security operation (Connell, J. H., Ratha, N. K., Zuo, J., 2017). Boundary feature is a feature used by Shah and Ross, in order to detect the limbic boundary and pupil boundary for iris segmentation (Jillela, R., Ross, A.A., 2013; Jillela, R., Ross,A., Boddeti, V.N., Kumar, B.V.K.V., Hu, X., Plemmons, R., Pauca, P., 2013). Next, is the edge feature where the edges in the image are detected and every point is obtained by the method used in order to represent a non-continuous and noncircular contour in the iris image (Jillela, R., Ross, A.A., 2013; Jillela, R., Ross,A., Boddeti, V.N., Kumar, B.V.K.V., Hu, X., Plemmons, R., Pauca, P., 2013).

Based on the definition of iris feature that been defined, there are no specific definition regarding the iris pigment spots. According to the iris image that been acquired by the Miles research, concern on the existence of the pigment spots (pointed by the arrow) on the iris surface, there is dynamic form of the pigment spots as presents in Figure 2.1.

Figure 2.1: The existence of the pigment spots on the iris surface.

The dynamic form means there is no specific shape of the pigment spots. There is no specific size. Next, there is no specific position of the pigment spots on the iris surface. Finally, there is no specific number of the existence (Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012; Man, M., Jabal, M.F.A., Rahim, M.S.M, Hamid, S., Yussof, W.N.J.W., 2018). This situation made it difficult to detect the existence of the pigment spots automatically. But, Edwards, M. (2016) and Edwards, M., Cha, D., Krithika, S., Johnson, M., Parra, E.J. (2016) had stated that the colour of the pigment spots is a range from tan to dark brown. The statement has given an opportunity for this study to solve the first issue. However, there is no specific data or numeric value had been published and can be used as a direction for this study to detect or extract the information regarding the pigment spots colour. Moreover, there is another difficulty to detect directly the pigment spots because the iris surface colour will interrupt the detection process. According to Edwards, the iris surface colour is commonly found in blue, green, and brown (Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012; Edwards, M., 2016; Edwards, M., Cha, D., Krithika, S., Johnson, M., Parra, E.J., 2016; Man, M., Jabal, M.F.A., Rahim, M.S.M, Hamid, S., Yussof, W.N.J.W., 2018).

Therefore, this paper has conducted a study to trace the pigment spots colour information in order to differentiate with the iris surface colour. Furthermore, the information from the pigment spots colour will be the key feature in this study to automate the detection process.

B. Filtering Approach

Filtering is a process of separating the irrelevant information from the region of interest (ROI) area. After knowing the feature that should be applied in this study, the next step is to recognise the relevant filtering approaches in order to separate the iris surface colour and pigment spots colour.

Earlier, many approaches have been proposed to detect or extract the colour feature. In this paper will discuss the most relevant approaches for colour feature detection. The purpose is to find out the most relevant approach in order to be applied in this study. Another approach characteristic to be concerned is less complexity.

Edwards, had employed CIE L*a*b* (CIELAB) colour space to measure the iris surface colour (Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012; Edwards, M., 2016; Man, M., Jabal, M.F.A., Rahim, M.S.M, Hamid, S., Yussof, W.N.J.W., 2018). The colour space had been defined in three dimensions, which are L* is a lightness coordinate, a* is a red-green coordinate, and b* is a blue-yellow coordinate. The benefit of this method is not limited to the iris pigmentation, but it is also useful to be used to study the genetic variation involved in iris textural patterns.

On the other hand, Miao et al., (2015) had proposed a method to detect the colour feature The method has filtered the red, green, blue (RGB) image into hue, saturation, value (HSV), hue, saturation, lightness (HSL) and hue, saturation, intensity (HSI) colour space model. But, there is no record regarding the name of the method, says S., Yussof, W.N.J.W. (2018).

Later, colour histogram is the prominent method to detect the colour feature (Srivastava, D., Wadhvani, R., Gyanchandani, M., 2015). The method has been categorised into two components. First is global colour histogram. It is to analyse every statistical colour frequency in an image. Second is local colour histogram, where the focus is to analyse the region of interest (ROI) in an image. Moreover, the second component will concern the spatial distribution of pixel, which is lost during the process of the first component. In the same report, Johnson et al. has employed histogram intersection method. The method was focused on the global colour feature used in the histogram. The performance of the method was influenced by the selected colour space. Furthermore, Johnson et al. had stated that the implementation of HSV and CIE L*a*b* colour space has boosted the performance of the method. In addition, colour histogram for K means (CHKM) is another well-known method had reported in the same publication.

Employed the colour histogram method in order to compute the number of occurrence of each unique colour in an image had been reported by Mary and Magneta (Mary, J.S. and Magneta S.C., 2016). The finding from the report is the successful story of the proposed method to yield the average precision and average recall in order to retrieve the contents in the image based on the texture, shape and colour features. In different case, Tiwari et al., used the colour segmentation method to segment the ringworm psoriasis on the skin (Tiwari, A., Marathe, A., Mondhe, P., Vashishth, S., Pawar, S.J., 2016). The infected part on the skin, which is the ROI is simply detected because the colour density is very high compared with the region is not infected.

Furthermore, Tan, K-W., and Stephen, I.D. (2013) had employed CIE L*a*b* colour space to study the sensitivity of people to colour differences in faces and skin-coloured patches. The finding from the study had found that the individuals are more sensitive towards the changes in a* and b*, compared with L*. In different cases, Beran et al. had implemented colour detection threshold approach in RGB and HSV colour space to detect objects on the chessboard (Beran, L., Chmelar, P. and Rejfek, L., 2016). The finding from the study had shown that the HSV colour space is better in detecting the object on the chessboard. According to Beran et al., the approach is easy to implement and possible to perform on any colour as long as the colour parameter is known. However, the approach is sensitive with the lighting of the scene. Hence, the approach need to convert the RGB colour space into the HSV colour space, and it is a long processing time. In addition, Beran et al., had stated that the RGB colour space is suitable for colour display, but it is a poor option for colour segmentation and analysis because of the high correlation among the R, G, B components. While, the HSV is a suitable colour space to be used for colour segmentation and analysis the colour image, because it is use separated colour information.

Based on the discussion, it has been found that there is possibility to use the colour detection threshold approach to detect the colour feature of the pigment spots. Moreover, the approach can be applied with the HSV colour space because of the stability of the colour space in the segmentation and analysis of an image. Table 2.1 shows the summary of the relevant approaches used for colour detection.

Table 2.1: Colour detection approach

No.	Author	Proposed Approaches
1.	Edwards, M. (2016)	CIE L*a*b* colour space
2.	Srivastava et al. (2015)	Colour histogram method
3.	Johnson, D., (1984)	Histogram intersection method
4.	Mary, J.S. and Magneta S.C. (2016)	Colour histogram method
5.	Tiwari et al. (2016)	Colour segmentation method
6.	Tan, K-W., and Stephen, I.D. (2013)	CIE L*a*b* colour space
7.	Beran et al., (2016)	Colour detection threshold approach
8.	Man et al., (2018)	Thresholding method through HSV colour space

Furthermore, based on the discussion, the HSV colour space is more suitable to be used in this study. The reliability of the colour space has open the opportunity for this study to filter between the pigment spots colour and the iris surface colour. The intensity of the pigment spots colour should be highest than the colour of the iris surface. Hence, there is more chances to separate between the pigment spots and the iris surface.

In addition, according to the finding found by Beran et al., this study had decided to employ the colour histogram method as the filtering method to detect the existence of the pigment spots on the iris surface (Beran, L., Chmelar, P. and Rejfek, L., 2016).. However, there is some improvement had to be done to the method in order to verify the detected objects on the image is a pigment spots. Hence, this study had proposed a new colour filtering method with adaptive the thresholding method and implement the method in the HSV colour space, which is namely as a spot filtering adaptive thresholding (SFAT) method.

METHODOLOGY

The proposed method consists of two main components, which are filtering part and segmentation part. In the filtering part, SFAT method has been applied. While in the segmentation part, boundary detection method has been used to segment the pigment spots.

A. Spot Filtering Adaptive Thresholding (SFAT) method

Figure 3.1 presents the methodology of the proposed method. The proposed method is possible to be developed in five main steps. The steps are: noise elimination, image conversion, thresholding, pixel elimination, and image enhancement.

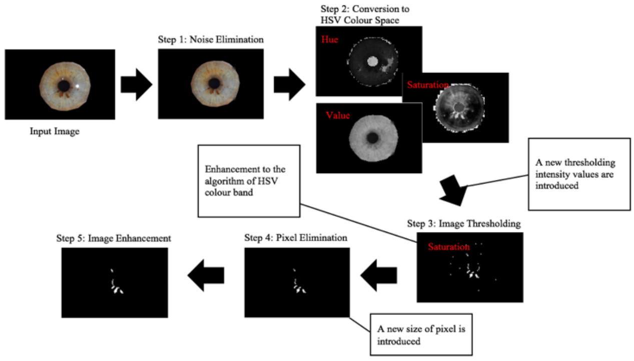


Figure 3.1: Methodology of the SFAT method

The first step shown in Figure 3.1 is the noise elimination process. The process is compulsory because is to avoid the interruption during pigment spots detection process. In this study, light reflection was considered as a noise. Figure 3.2 shows the sample of the data that contain the light reflection.

Figure 3.2: Sample of iris image contain light reflection

The elimination process starts with read the input image (*I*) then convert *I* to the grey scale colour space (*GI*). The conversion algorithm can be expressed in the mathematical equation as shows in (3.1),

$$GI = 0.2989 * R_I + 0.5870 * G_I + 0.1140 * B_I \qquad (3.1)$$

where *GI* is the grey scale image. R_I is the value of the red colour from the input image, G_I is the value of the green colour from the input image, and B_I is the value of the blue colour from the input image. Next, the GI will be converted into binary image (*BI*). The purpose is to detect the existence of the light reflection on the iris surface, where the light reflection on the image is contain high intensity value compare with other colours. The existence of the light reflection can be seen in the image as a white spot on the iris surface. Moreover, during the conversion process the threshold value has been set as 220, where the pixel in the image that contain the value greater or equal 220 the pixel value will be changed into 1 and others will be changed into 0. Then, the process is continued with the dilation to fill the hole with a new pixel value. The new pixel value was taken from the nearest neighbour pixel. The final process is to reassemble the RGB colour. The process is as shown in Figure 3.3.

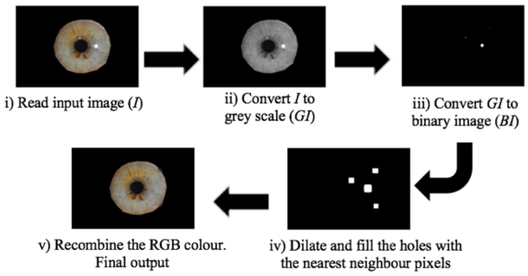


Figure 3.3: Noise elimination process

The second step is the conversion process, where the image will be converted from the RGB into HSV colour space. The conversion algorithm as shown in (3.2) to (3.8),

$$R_n = \frac{R}{2^b};\ G_n = \frac{G}{2^b};\ B_n = \frac{B}{2^b} \qquad (3.2)$$

where R_n, G_n and B_n are normalised RGB components and the result is in range from 0 to 1. Besides b is a length for each colour component.

$$C_{max} = \max(R_n, G_n, B_n) \qquad (3.3)$$

$$C_{min} = \min(R_n, G_n, B_n) \qquad (3.4)$$

$$\Delta = C_{max} - C_{min} \qquad (3.5)$$

where C_{max} is the maximum value from normalised RGB component and C_{min} is the minimum value from normalised RGB component.

$$Hue = \begin{Bmatrix} 0° & if\ \Delta = 0 \\ 60° \cdot \left(\frac{G_n - B_n}{\Delta} mod\ 6\right) & if\ C_{max} = R_n \\ 60° \cdot \left(\frac{B_n - R_n}{\Delta} + 2\right) & if\ C_{max} = G_n \\ 60° \cdot \left(\frac{R_n - G_n}{\Delta} + 4\right) & if\ C_{max} = B_n \end{Bmatrix} \qquad (3.6)$$

$$Saturation = \begin{Bmatrix} 0 & if\ C_{max} = 0 \\ \frac{\Delta}{C_{max}} & if\ C_{max} \neq 0 \end{Bmatrix} \qquad (3.7)$$

$$Value = C_{max} \qquad (3.8)$$

The output from the conversion process is a separated colour information, which are hue, saturation and value images as presents in Figure 3.4.

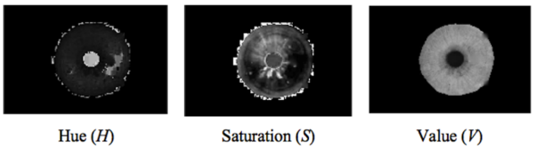


Figure 3.4: Separated colour information

The third step is the thresholding process. The process was conducted to all three images individually. In this process, a new thresholding intensity values are proposed by this study. The purpose is to filter the pigment spots from the iris surface. The new intensity value is the colour feature of the pigment spots. The algorithm of the process has been shown in (3.9). The algorithm will assign a low and high threshold intensity values for each colour band. The minimum and maximum values for every low and high threshold for each colour band are in a range of 0 to 1. The low and high threshold values influence the colour intensity values (Man, et al., 2017).

$$f(x) = \begin{cases} \alpha_l^h & \begin{matrix} h = j \\ l = k \end{matrix} \\ \beta_l^h & \begin{matrix} h = m \\ l = n \end{matrix} \\ \gamma_l^h & \begin{matrix} h = p \\ l = q \end{matrix} \end{cases} \qquad (3.9)$$

where x is the function of set of the thresholds, α is the hue image, β is the saturation image, γ is the value image, h is the high threshold value, l is the low threshold value, and j, k, m, n, p, q are the proposed values by this study as presents in Table 3.1.

Table 3.1: Proposed value for thresholding intensity colour value

j	k	m	n	p	q
0.20	0.01	0.90	0.70	0.50	0.01

Then, the process continues with the masking process. The process is to find the high intensity value of colour in every pixel for each colour band. The purpose is to classify the high and low intensity value. The process can be expressed in the following algorithms from (3.10). In this process, the enhancement towards the algorithms of the HSV colour bands have been introduced (Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012).

$$f(\beta_\Delta) = (\beta_i \,/\, \beta_l) \cap (\beta_i \leq \beta_h) \qquad (3.10)$$

where β is the saturation, Δ is the mask, i is the image, l is the low threshold value, and h is the high threshold value. The output from the process is as shown in Figure 3.5.

Figure 3.5: Masked of saturation

The fourth step is irrelevant pixel elimination. Proceed with the process only the masked of saturation image will be used in order to detect the pigment spots. The reason only the masked of saturation image will be used for this process is because the image has highlighted the key information regarding the pigment spots compared with the other masked images. The pixel size that will be eliminated has been proposed by this study is less than 80. The algorithm will be used in this process as shown in (3.11) and (3.12),

$$f(y) = (x_i, k) \tag{3.11}$$

where x_i is come from (3.12):

$$x_i = (\alpha_\Delta \cap \beta_\Delta \cap \gamma_\Delta) \tag{3.12}$$

where $f(y)$ is the function to eliminate the small pixels less than k pixels. x_i is the mask of the colour object, α is the hue, β is the saturation, γ is the value, Δ is the mask, and k is the pixel size that want to be eliminate. Figure 3.6 shows the output after the elimination process.

Figure 3.6: Result from the elimination process

The fifth step is image enhancement. The process is to tidied up all borders of the detected area in the image. Morphological closing operation function has been employed to proceed with the process. Then the process continued with filling up of any holes found in the image by change the pixel value with 0. Figure 3.7 presents the output from the process.

Figure 3.7: The final output from the process of SFAT method

B. Iris Pigment Spots Segmentation

The proposed method for the segmentation process was consists of three steps, which are conversion of indexed image into RGB image, conversion of RGB image into grey scale image, and edges detection. Figure 3.8 illustrated the steps included in the method.

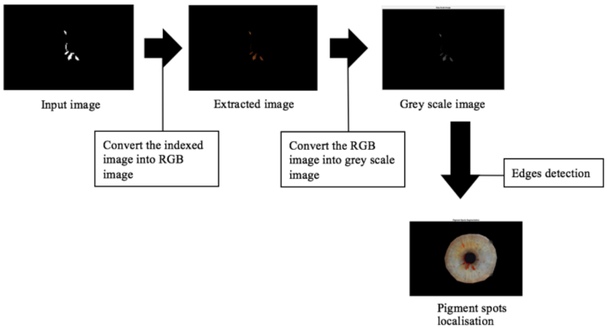


Figure 3.8: Iris pigment spots segmentation method

The final output from the filtering process, which is known as enhancement image will be an input to this process. The enhancement image is in the form of indexed image, where the data type of the image is in the logical array format. Hence, to localise the pigment spot, there is need to convert the image into the RGB colour space. The conversion processes can be expressed as equations as shown in (3.13) to (3.16). The purpose of the conversion is to put the image back into the original colour, where during the filtering process the image has been converted into the HSV colour space and indexed image. The main reason to put the original colour back on the image is to verify the correct colour has been filtered. The process started with the conversion of the data type of enhancement image same as the data type of the original image as shown in (3.13). Currently the data type of the enhancement image is a logical and the original image is a double.

$$I = cast(enhancement\ image\ 'like'\ original\ image) \quad (3.13)$$

where I is the output image. While $cast$ is a conversion function that converts $enhancement\ image$ to the same data type and sparsity as variable $original\ image$. If $enhancement\ image$ and $original\ image$ both real, then I is also real. Next process is convert the I image into the RGB colour space. The processes can be expressed as following equations from (3.14) to (3.16). However, the output from the process is a separated colour component, which are red, green and blue components.

$$I_{Red\ Comp} = I .* original\ image(:,:,1) \quad (3.14)$$

$$I_{Green\ Comp} = I .* original\ image(:,:,2) \quad (3.15)$$

$$I_{Blue\ Comp} = I .* original\ image(:,:,3) \quad (3.16)$$

The final process is combine all the RGB components as one component and the equation can be referred in (3.17).

$$I_{RGB} = cat(3, I_{Red\ Comp}, I_{Green\ Comp}, I_{Blue\ Comp}) \quad (3.17)$$

where I_{RGB} is a final output of the first step, known as extracted image. While cat is a concatenate function to combine all the colour components.

Receiving an input from the previous step, the process proceeds with the conversion of the image from RGB colour space into grey scale image. The purpose is to convert the data type of the image from double into logical array data type. The conversion process can be expressed as an equation in (3.18).

$$I_{Grey} = 0.2989 * R + 0.5870 * G + 0.1140 * B \quad (3.18)$$

where I_{Grey} is an output from the process, known as grey scale image. While R, G and B is separated red, green and blue colour components.

The final step is edges detection. The edges detection method has been used in this process. The purpose is to search the edges of the ROI image. The processes can be expressed as the following equations from (3.19) to (3.23),

$$E = bwboundaries(I_{Grey}) \quad (3.19)$$

where E is an edge will be detected. While $bwboundaries$ is a function to trace the region boundaries in the logical array data type.

$$NoE = size(E, 1) \quad (3.20)$$

where NoE is a number of edges found. The $size$ is a function to return the number of the boundaries found in the image.

$$\sum_{k=1 \ldots NoE} [N \quad 2] = E\{k\} \quad (3.21)$$

where k is a number of loops. The loop will pull N by 2 arrays from the k^{th} cell.

$$x = [N \quad 2](:,2) \tag{3.22}$$

$$y = [N \quad 2](:,1) \tag{3.23}$$

where x and y is coordinate values use to draw the boundary, that was retrieved from the arrays N by 2.

EXPERIMENT

The experiment has been conducted by using Miles research digital iris images. The images have been prepared by the Miles research company. The images have been acquired by using PV320C. The size of the images is 1749 x 1184 pixels in 256 dpi resolutions. The format of the images is in Joint Photographic Experts Group (jpeg). The images are stored in 24-bits RGB colour space (Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012; Johnson, D., 1984; Man, M. Jabal, M.F.A., Rahim, M.S.M., 2016; Miles Research., 2013). There are 262 images have been used in this experiment.

Later, the performance of the proposed method been evaluated by using the standard performance metrics, which are false acceptance rate (FAR), false rejection rate (FRR), and detection rate (DR)(Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012; Bhoyar, K.K. and Kakde, O.G., 2010; Doukim, C.A., Dargham, J.A., Chekima, A., 2009). Further description is presented in Table 4.1.

Table 4.1: Standard performance metrics description

Standard Performance Metrics	Description
FAR	i. Incorrect segmentation of pigment spots on the image that contains pigment spots
FRR	i. Do not perform the pigment spots segmentation from the image that contains pigment spots. **OR** ii. Performed a pigment spots segmentation on the image that do not contains pigment spots **OR** iii. Totally perform incorrect segmentation on the image that contains pigment spots
DR	i. Correct pigment spots segmentation on the image that contains pigment spots. **OR** ii. Do not perform pigment spots segmentation on the image that does not contains pigment spots.

Moreover, the equation for all standard performance metrics as shows from (4.1) to (4.3).

$$FAR = \frac{No.of\ Incorrect\ Segmentation}{Total\ Tested\ Images} \times 100\% \qquad (4.1)$$

$$FRR = \frac{No.of\ Segmentation\ Error}{Total\ Tested\ Images} \times 100\% \qquad (4.2)$$

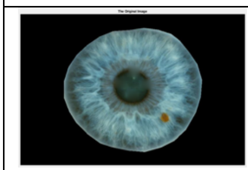
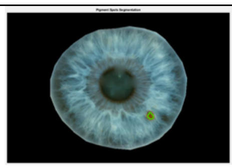
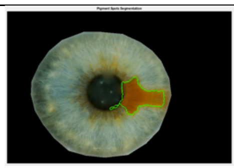
$$DR = \frac{No.of\ Accurate\ Segmentation}{Total\ Tested\ Images} \times 100\% \qquad (4.3)$$

RESULTS AND VALIDATION

A. Result

The result from the conducted experiment shows that the proposed approach was successful to segment the pigment spots on the iris surface. Table 5.1 presents the sample of the result that the pigment spots on the iris surface was successful segmented accurately from the 262 of tested images.

Table 5.1: Result of pigment spots segmentation

Original Image	Segmented Image
	
	

The percentage of the *DR* that has been recorded in this experiment is 37.02%. Then, the percentage of the *FAR* is 14.5%. Next, the percentage of the *FRR* is 48.47%. Table 5.2 shows the comparison towards of segmentation approaches, in order to evaluate the performance.

Table 5.2: Comparison of segmentation approaches

Approaches	**DR (%)**	**FAR (%)**	**FRR (%)**
1. Geodesic Active Contour (Man, M., Jabal, M.F.A., Rahim, M.S.M., 2012)	13.36	17.18	69.47
2. Thresholding method through HSV colour space (Man, M. et al., 2018)	25.30	4.00	70.70

3. Boundary Edges Detection (Proposed)	37.02	14.50	48.47

Based on Table 5.2, the proposed approach shows the improvement around 11.72% of accuracy, compared with the previous approach tested by the author. Moreover, the *FRR* percentage has been reduced into 22.23%, which means most of the pigment spots on the iris surface was successful detected.

Furthermore, the finding from the conducted experiments it was found that the previous segmentation approaches have an issue to extract the colour feature. This situation has make difficulty to the approach in order to extract the correct feature for segmentation purposes.

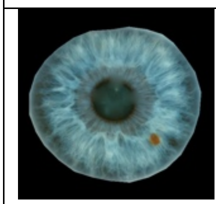
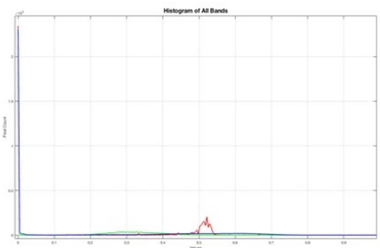
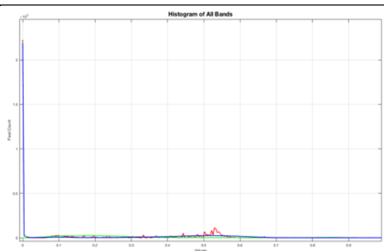
Hence, the proposed approach has been developed with the colour filtering method, namely Spot Filtering Adaptive Thresholding (SFAT) method. The method works as a filter, which is to separate the pigment spots colour with the iris surface colour.

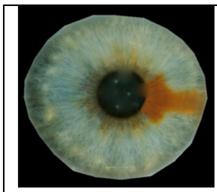
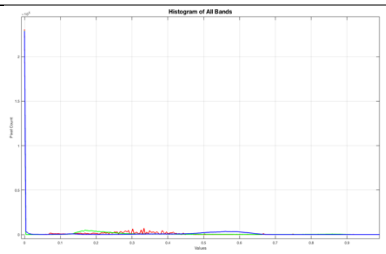
B. Validation

In this section, the discussion will be focused on the validation of the SFAT method as a filter in the segmentation approach. The main concern in this validation process is the accuracy on the detection of the pigment spots colour feature.

According to Man et al.,(2018), the threshold intensity values for every colour are strongly influences the detection process. Based on the threshold intensity values have been proposed, there is a colour histogram pattern that related with the pigment spots colour feature. Table 5.3 shows the colour histogram of the iris image.

Table 5.3: Colour histogram pattern

Input Image	**Histogram**
	
	

Based on Table 5.3, pattern of the histogram towards the image that contains the pigment spots is where the Hue energy will be increased higher than other energies. The value of increment for the Hue energy is basically between 0.3 and 0.6. During this range normally, the Saturation and Value energy is lower than Hue.

Result from the histogram has highlighted the existence of the pigment spots on the iris surface, when the intensity of the pigment spots colour is higher than the colour of the iris surface. It is possible to be seen on the saturation colour space. Figure 5.2 shows the existence of the pigment spots on the iris surface after the colour histogram process. Therefore, only the saturation colour space has been used for the next step on the process.

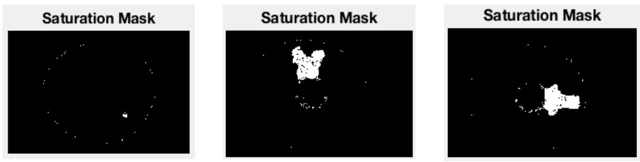


Figure 5.2: Result from the histogram process

Continue the process is the masking process, where the purpose is to convert the pixel colour with the low intensity value into 0 and the pixel colour with the high intensity value into 1. The result from this process is the pigment spots extraction. Figure 5.3 presents the extraction result.

Figure 5.3: Pigment spots extraction

Furthermore, a comparative study on the colour detection method has been conducted in order to evaluate the SFAT method performance. Concern of the comparative study is on the accuracy of the colour detection, the complexity of the method, and the processing time. Table 5.4 presents the result from the study. The comparative study was compared between the previous method, namely simple colour detection in HSV colour space and SFAT method, where the previous method has been tested and the result was published by the author.

Table 5.4: Comparative study

Method	Accuracy (%)	Method Complexity	Processing Time – Average (s)
Simple Colour Detection in HSV Colour Space (Man, M. et al., 2018)	25.30	Low	11.27
SFAT method (proposed)	**60.38**	**Low**	**9.28**

Based on the Table 5.4, the proposed method has showed the improvement 35.08% of detection accuracy. The complexity of the method is also low and easy to be employed. In addition, the average of the processing time is less than 10 second per image. Generally, the SFAT method shows the impressive improvement in accuracy and processing time.

CONCLUSION

Spot filtering adaptive thresholding (SFAT) method has showed the impressive improvement in detecting the existence of the pigment spots on the iris surface. In different perspective, SFAT has successful to filter between the pigment spots colour feature and the iris surface colour feature. Furthermore, the intensity values of the thresholding, which is been proposed in this study and the improvement towards the colour feature detection algorithm was discovered the intensity of the colour feature of the pigment spots on the iris surface. Moreover, the SFAT method has improved the accuracy of the segmentation process in order to segment the pigment spots on the iris surface. Based on this achievement, the improvement towards the algorithm and the proposed intensity value can be recognised as a contribution by this study in the medical imaging area.

In addition, the finding from this study is the key problem towards the segmentation approaches to segment the iris pigment spots, in which no available method to filter the colour features between the pigment spots and iris surface. Hence, this study has proposed the SFAT method to overcome the problem. However, the most challenging part in this study is to recognise the colour features of the pigment spots and the iris surface, because the worst situation is to recognise the colour features on the iris surface where is the variation colour of the iris surface is different from one to another. Nevertheless, to solve the problem, this study had decided to recognise the colour feature of the pigment spots, which is much easier compare to the colour feature of the iris surface. Therefore, by filtering the colour feature of the pigment spots, which means the process will automatically separate the pigment spots from the iris surface, regardless by knowing the colour feature of the iris surface. This solution has successful to produce the expectation output of the study.

Although, the accuracy of the detection and segmentation of the pigment spots on the iris surface is not achieve more than 90%, still it is a contribution by this study, because according to Edwards, there is an open problem in the research, where there is a difficulty to make an automation system to detect the pigment spots in order to categorise either the pigment spots is a nevi or freckles (Edwards, M., 2016). Moreover, based on the observation towards the publications that related with the iris, most of the research articles are focused on the biometrics research or retinopathy research, which means it is rare publication or research that focus on the iris pigment spots research. Hence, this contribution can be considered as an initial step to close the gap that stated by Edwards in 2016, where this study was successful to automate the iris pigment spots detection process.

On the future work, the aim of this study is to improve the accuracy of the detection process. The open problem from this study is to find the method in order to classify the iris pigment spots, either it is fall under the nevi or freckles categories. The purpose to classify the pigment spots is to make an initial step in order to detect the eye cancer that cause by the iris nevi.

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