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RANGE DETECTION OF STRABISMUS BASED ON THE DISTANCE AND COORDINATES OF THE IRIS

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ABSTRACT

Strabismus is a failure of the two eyes to maintain a proper alignment with each other. It usually occurs because of the poor eye muscles control or on a very farsighted person. It also can occur in all stages of age. A timely diagnosis is required to prevent it from getting worse. However, the traditional screening method is done manually, require expertise, costly and timely. Thus, this research proposed a semi-automated range detection system based on the distance and coordinates of the iris. It can help to reduce the time for the ophthalmologist to diagnose the strabismus. This proposed system consists of three stages: (1) Pre-processing to remove noise and enhance the original image. (2) Locating the iris location (3) Classification into strabismus types. The sample images are taken from publicly online dataset: The Columbia Gaze dataset (CAVE) and Kaggle: Eye Disease dataset. It will be used as the input image for the system. By utilizing the image processing approach, this system will be able to assists the ophthalmology and health care practitioners as strabismus screening tools.

1.0 INTRODUCTION

There are many eye disorders can occur in children, adult as well as the new born. Strabismus and amblyopia are one example of eye disorder that can occur in all three generations. Strabismus (squint, cross eyed) is a misalignment of the eyes that can occur in the horizontal or vertical direction (Costakos, 2017). The strabismus occurs in 1.3-5.7% of all children. Most individuals with the strabismus have one eye that has better vision than the other, the deviating or non-fixating eye is designated. Experienced clinicians agree that strabismus is a heterogenous disease and clusters in the families. Population studies support a hereditary component with a prevalence in siblings of an affected individual ranging from 11% to 70% (Bateman & Isenberg, 2013). There are four types of strabismus which are the esotropia (inward turning), exotropia (outward turning), hypertropia (upward turning) and hypotropia (downward turning) as shown in figure 1.

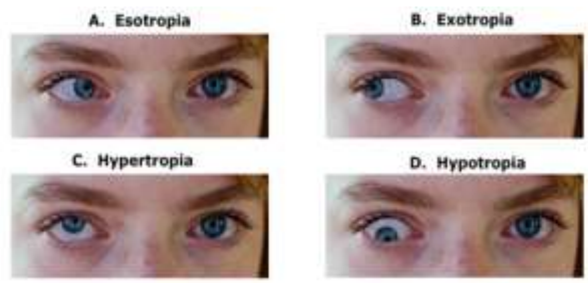


Figure 1. Types of strabismus (Bangalore West Lions Superspeciality Eye Hospital, 2019)

The causes of strabismus are poorly understood and the history is different in children and adults (Bateman & Isenberg, 2013). As it also can occur to people with diseases such as thyroid, diabetes and if the person has head injury or trauma. Also, the previous strabismus diagnosis need to be conducted manually by the ophthalmologist which included cover test, Hirschberg test, Maddox test, and others (Chen, Fu, Lo, Chi, & Xu, 2018). Therefore, to saves times and reduce the work for the ophthalmologist a digital strabismus detection is developed within time. This system also is suitable for the remote area and for the health campaign that involves a big community to saves time and cost (Khumdat, Phukpattaranont, & Tengtrisorn, 2013). Therefore, this semi-automated strabismus detection system can help to provide a valuable computer aided diagnosis.

To test the performance of the system, there are two datasets which several random images from each dataset will be selected as the inputs for the research. The two datasets can be found on online platform which are the Columbia gaze dataset (CAVE) and the Kaggle: eye disease dataset.

The structure of this paper is presented as follows; Section 2 a brief literature review on the previous research method that have been used. In Section 3, a sequence of explanation on the proposed methodology. While, Section 4 discuss the results of the finding. Finally, a general conclusion is given in Section 5.

2.0 LITERATURE REVIEW

There are many research have been done by the previous researchers to develop a system that can help the expertise to determine the strabismus. There are usually three stages that will be conducted to get the result of the strabismus which are: (1) Pre-processing (2) Feature Extraction and (3) Classification. However, there are only a few research that help to determine the types of the strabismus. The common previous research only determines either the person has the strabismus or not.

Many methods have been used in the previous research to develop the system. Abubakar Yamin et al. build a hardware to diagnose the paralytic strabismus using the computer aided diagnosis. The authors proposed a technique that is based on the traditional Hess Screen Instrument. The image is acquired by using a Logitech C252 HD webcam. Median filter is applied in the pre-processing stage. The last stage diagnosed the types of strabismus based on the analysis that are acquired from the test conducted by the doctor earlier from the traditional Hess charting. The system also used the Fuzzy logic technique to analyse the system (Yamin, Khan, & Yasin, 2013).

A tracking system for strabismus assessment based on the cover test is built by Yang Zheng et al. The system consists of the stimulus module to conduct the cover test and video acquisition module for motion capture (high-speed camera RER-USBFHD05MT). The cover test is conducted by using the occluder, which are moving alternately between left eye and right eye. After acquiring the video, to analyse the result, it is based on the Harr feature and ellipse fitting. The deviation during the stimulus process are also calculated through pupil localization to assess the result of strabismus (Zheng, Fu, Li, Lo, & Wen, 2018; Zheng et al., 2019).

Zeng Hai Chen et al. develop a digital system for strabismus diagnosis based on eye tracking technique. An eye tracker Tobii X2-60 is used to capture the gaze data. After the data is obtained, strabismus occurrence feature needs to be defined to determine whether the subject has strabismus or not. There are two features which are the fixation deviation and fixation contrast. After that, strabismus direction feature is employed to determine the direction of the strabismus whether it is vertical or horizontal. Then, it will be classified into their types (Liang, Fu, Lo, & Xu, 2017).

Analyn N. Yumang et al. creating a system that used the image processing via OpenCV python and conducted central corneal light reflex (CCLR) test or known as Hirschberg test (HOCORC) to classify the strabismus. The method used to extract the face is the snake model, followed by image thresholding and circular Hough transform for the eye detection. Then, HORORC locate the centre of the cornea detected, by retrieve the coordinates of the boundary from the circular Hough transform result. Then, the resulting value is compared to the reference table of CCLRR values, to check either the person has the strabismus or not (Yumang, Marquez, Paglinawan, Yamson, & Cuevas, 2019).

A work that can assist in diagnosis of syndromic strabismus via digital imaging is presented by J.D.S. de Almeida et. al. The study intends to serve both for preliminary checking and aiding in the diagnosis. The image is captured at the eye clinic using a camera SonyR Cyber-Shot with 2048 x 1536 pixel resolution. There are five steps is organized to obtain the result. (1) Segmentation of face, the RGB image is converted to YCbCr to derive the map of skin colour (2) Detection of the eye region, using homomorphic filtering, gaussian filtering and Sobel filter (3) Detecting the location of eyes, using Hough transform based on the orientation annulus operator and geostatistical functions (4) Locate the location of the limbus and the brilliance, using Hough transform and Canny filter (5) Diagnosis of strabismus, using the location of the corneal light reflection generated by the Hirschberg's test and the limbus location (Sousa de Almeida, Silva, Teixeira, Paiva, & Gattass, 2015; Valente, de Almeida, Silva, Teixeira, & Gattass, 2017).

Although there were many research have been done. Improvements can still be made in certain aspects. This research proposed a system that can help to classify the strabismus into their types based on the distance and coordinates obtained and provide some data on the misalignment of the eyes. Thus, this system can be used as the pre-screening tools to be used in the remote area or in health campaign to make it easier for the ophthalmologist to diagnose the result of the strabismus faster.

3.0 METHODOLOGY

There are four stages are conducted in this proposed system which are the image acquisition, pre-processing, locating the glint on the iris and distance and lastly the classification for the strabismus types. The proposed screening system will use the MATLAB (R2018b) image processing toolbox to develop the algorithm for the detection. While the input images are taken from the publicly available dataset: The Columbia Gaze Dataset (CAVE) and Kaggle: Eye Disease dataset. Figure 2 displays the proposed system architecture for the strabismus classification. While figure 3 shows the flow of the proposed detection system using MATLAB.

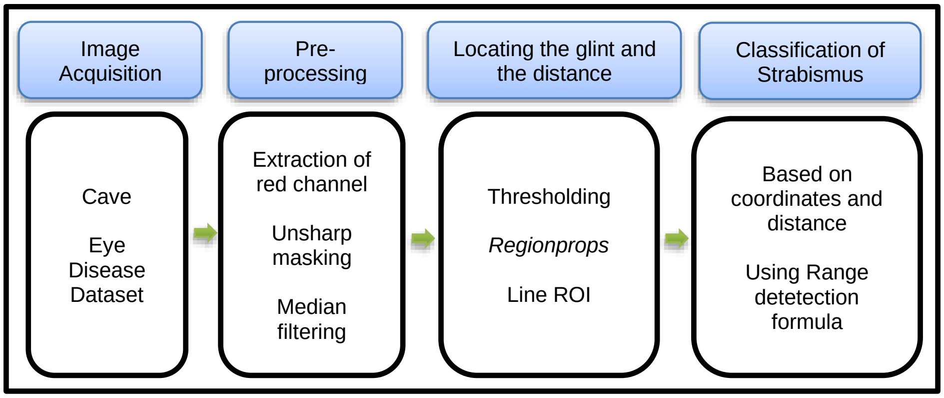


Figure 2. The proposed system architecture for strabismus detection

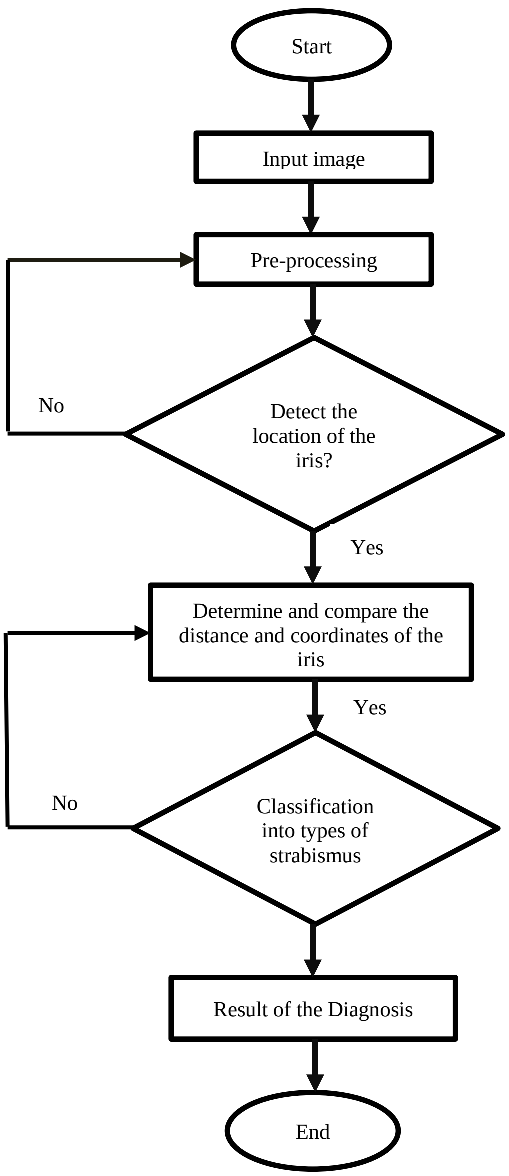


Figure 3. The flowchart for the detection of the strabismus

There are several processes need to be conducted for the system to classify the strabismus into their types.

3.1 Image Acquisition

Ten sample images have been tested to evaluate the proposed detection system. The images are taken from the CAVE and Kaggle: Eye Disease dataset. These online datasets are easy to access and freely available to anyone. Furthermore, the two datasets are well known and have been cited by many previous researchers (Zaki, Zulkifley, & Nazari, 2014). Also, the datasets consist of digital images of individuals that are suitable to be used for the research.

The first process is to select the images from the datasets. The images are selected randomly to proves that all the images from the datasets can be evaluated by the system. 5 images are taken from CAVE and another 5 images have been taken from Kaggle: Eye Disease dataset to test the system. The focus of chosen the dataset is based on the individual with strabismus but due to limited online dataset available, one of the datasets have no strabismus subject. Therefore, the CAVE datasets, which have no images of individuals with strabismus is selected to be compare with the individuals with strabismus results.

3.2 Pre-processing

The pre-processing stage is conducted to remove the noise and help to enhance the colour in the original image. There are several methods is used to get a suitable image for further processing. Firstly, the red channel extraction from the RGB image. The red channel has the highest intensity to detect the iris compared to green and blue channel. Then, unsharp masking is applied to sharpen the image. The unsharp masking technique comes from a publishing industry process in which the image is sharpened by subtraction the blurred version of the image from itself. As shown in equation (1):

$$f_s(x,y) = f(x,y) - \bar{f}(x,y) \tag{1}$$

Where, $f_s(x,y)$ denotes the sharpened image obtained by unsharp masking, which $\bar{f}(x,y)$ is the blurred version of $f(x,y)$.

After that, the median filter is used to remove the remaining noise from the image. It can remove salt and pepper noise without significantly reducing the sharpness of an image (Zolkifli & Nazari, 2020).

3.3 Locating the glint on the iris and the distance

The next stage is to locate the glint on the iris to get the coordinates and to measure the distance between the glint on the iris and the inner corner of the eyes. This data helps to classify the strabismus into their types.

3.31 Locating the glint on the iris

The result from the pre-processing stage is then used to get the binary image for this stage. The grayscale image is binarized by the thresholding method (Li, 2017; Nazari, Mustafa, & Zulkifley, 2015). After the binary image is obtained, then region props from the image processing toolbox is used to analyse the original grayscale pixel values corresponding to each object in the binary image. This algorithm is used to calculate the centroid of objects found in the binary image. In this case, the object is the irises. It gives the coordinates data for the two-iris found on the image. The centre detected is based on the location and intensity value, returned as a *p*-by-Q vector of coordinates. The first element is the horizontal coordinate (x-axis) while the second element is the vertical coordinate (y-axis). This data is important to determine the types of strabismus (The MathWorks Inc., n.d.).

3.32 Measure the distance between the glint and the inner corner of the eyes

To measure the distance, firstly, the algorithm will get the size of the image. Then, it will gather the data to be stored with each ROI. The user needs to manually create the line ROI from the glint until the inner corner of the eyes. It used a Callback function to interact with the user. The distance between both eyes is compared to detect if there are abnormalities present. The data of the distance that have been obtained are needed to identify either the individuals have strabismus or not (The MathWorks Inc., n.d.).

3.4 Classification of Strabismus

The classification of the strabismus is based on the data that have been obtained from the previous stage. The equation for determine the range detection is as shown below:

$$D_D = I_L - I_R \tag{2}$$

Where, D_D stands for distance different, while I_L is the left iris and I_R is the right iris. This equation is used to get the different in distance between both irises.

$$Coordinates_x = I_{Lx} - I_{Rx}$$

$$Coordinates_y = I_{Ly} - I_{Ry} \tag{3}$$

Where, I_{Lx} and I_{Ly} is the x axis and the y axis of the left iris, while I_{Rx} and I_{Ry} is the x axis and the y axis of the right iris. This equation is used to get the difference in coordinates of both irises for x axis and y axis.

Strabismus can occur on both eyes. Therefore, the positive and negative from the results can be ignored. The aim is to find the difference in distance and the coordinates between both irises.

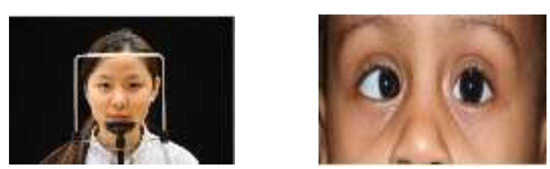
4.0 RESULTS AND DISCUSSION

The proposed method is evaluated on two online datasets which are the CAVE and Kaggle: Eye Disease Dataset.The CAVE is a large publicly available gaze dataset known as Columbia gaze dataset. The dataset consists of 5880 images of 56 different subject range from 18 to 36 years old which 32 of them are males while the remaining 24 are the females. There are 5 head poses and 21 gaze directions per head poses for each the subject. The dataset is created to train a detector to sense eye contact in an image using a passive, appearance-based approach. The subjects chosen are ethnically diverse and there are 21 subjects that wore glasses. Each image has a resolution size of 5184 x 3456 pixels. The images were captured using a Canon EOS Rebel T3i camera and a Canon EF-S 18-135 mm IS f/3.5-5.6 zoom lens (Smith, Yin, Feiner, & Nayar, 2013).

Then, Eye disease dataset is obtained from Kaggle. It is a dataset to predict the human eye diseases created by Kondwani. The dataset contains five types of diseases which are the bulging eyes, cataracts, crossed eyes, glaucoma, and Uveitis. Therefore, only image with crossed eyes (strabismus) will be chosen as the subjects of the research (Kondwani, 2019).

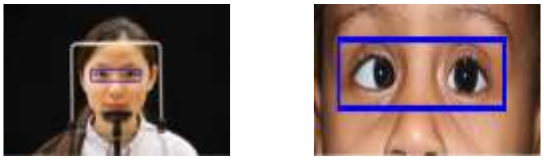
4.1 Pre-processing

The first stage to start the detection system is the pre-processing. The pre-processing helps to remove the noise and enhance the original image to be used for further processing. Figure 4 to 8 shows all the result image of the selected method for pre-processing. Figure 4 shows the original input image from the CAVE and Kaggle: Eye Disease dataset. Then, in figure 5, the eye area is crop out from the face image to avoid false detecting. It is to minimize the area for the detection region.



(a) (b)

Figure 4. The original image (a) CAVE (b) Eye Disease Dataset



(a) (b)

Figure 5. Images of cropped area of the eyes (a) CAVE (b) Eye Disease Dataset

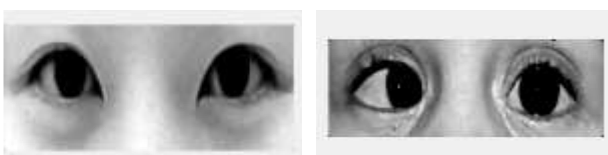
Figure 6 displays the image result for the extraction of the red channel from RGB image. Then, unsharp masking is applied to sharpen the image as in figure 7. After that, figure 8 shows the result after median filter is applied. The image appears smoother than before.

(a) (b)

Figure 6. Red channel extraction image (a) CAVE (b) Eye Disease Dataset

(a) (b)

Figure 7. After unsharp masking image (a) CAVE (b) Eye Disease Dataset

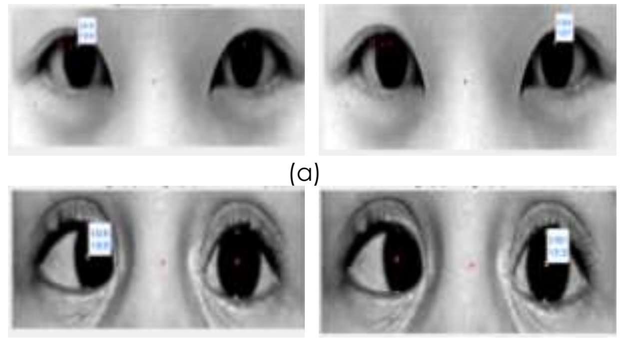


(a) (b)

Figure 8. After median filtering image (a) CAVE (b) Eye Disease Dataset

4.2 Locating the glint on the iris and the distance

Figure 9 displays the result image of the glint detection. As shown in the image, the centre of the iris is located on the top of the glint represents by the red dots. Therefore, based on the glint location, the strabismus types can be determined. For the CAVE image, it detects more than 1 centre for each iris. But, as long as it detects the correct glint, the coordinates are still correct. The other point detected should be ignored. For the eye disease dataset, the centre is detected correctly with only 3 point of centre are detected.



(a)

(b)

Figure 9. Images of glint detection with coordinates for right and left eye (a) CAVE (b) Eye Disease dataset

Figure 10 exhibit the result of the distance between the iris and the inner corner of the eyes for both eyes. The distance between both irises are compared to determine if there are abnormalities present. While Table 1 shows the coordinates and distance data on the ten images tested. Due to limited image of strabismus available in the datasets, only two types of strabismus can be detected which are the esotropia and hypertropia. The different in distance and coordinates are calculated to determine the range for the normal individual, individual with esotropia and individual with hypertropia types.

(a) (b)

Figure 10. Distance image between iris and inner corner of the eye (a) CAVE (b) Eye Disease Dataset

Table 1. The result of the distance and coordinates for cave and eye disease dataset

CAVE						
Image	Distance (pixels)		Coordinate of left iris		Coordinate of right iris	
	Left iris	Right iris	x-axis	y-axis	x-axis	y-axis
Image 6	61.2	59.3	90.47	43.03	326	25.68
Image 12	52.4	51.8	76.91	41.09	304.2	36.99
Image18	65.1	66.3	96.01	34.18	341.7	38.24
Image 21	59.7	58.9	87.94	32.43	308.8	29.62
Image 29	62.8	62.9	97.97	29.43	344.9	28.7
Eye Disease Dataset						
Image	Distance (pixels)		Coordinate of left iris		Coordinate of right iris	
	Left iris	Right iris	x-axis	y-axis	x-axis	y-axis
Image 1	23.5	19.7	39.67	18.92	140.4	20.87
Image 6	28.5	22.5	56.1	30.74	168	31.5
Image 12	24.8	36.7	64.84	32.53	194.1	20.38
Image 10	22.4	29.4	62.65	29.25	185.1	31.33
Image 37	15.8	13.0	31.45	16.71	102.61	14.5

4.3 Strabismus Diagnosis

Table 2 shows the range that can be deduced from the previous result. The most common strabismus types can be found in children are esotropia and exotropia (Boyd, 2020). However, there are no exotropia types found in Eye Disease dataset. Based on the range, image 37 are the only hypertropia types found in the eye disease dataset while the other four images are classified in esotropia types. For the CAVE, all the images are classified into normal individual.

Table 2. Range of eyes for normal and strabismus individual with esotropia and hypertropia types

Types of eyes	Distance different	Coordinates different	
		x-axis	y-axis
Normal	0.1 < 2.0	220 < 250	0.6 < 17.35
Esotropia	3.8 < 12.0	111 < 130	0.76 <13
Hypertropia	2.8	71.15	2.21

5.0 CONCLUSION

This paper proposed a range detection system for strabismus based on the distance and coordinates of the iris. Two datasets are used to validate the proposed system which are the CAVE and the Eye Disease dataset. The results for the pre-processing able to give better images based on the result of glint detection in the next stages. Then, the method used for measuring the distance and coordinates also able to perform well although there is a bit noise in detecting the glint. However, the drawback of this system is it cannot determine the strabismus automatically. Thus, the future work should improve on the automated strabismus detection based on the distance and coordinates of the irises.

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