35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

# Automatic Screening of Narrow Anterior Chamber Angle and Angle-Closure Glaucoma Based on Slit-Lamp Image Analysis by Using Support Vector Machine

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*Abstract*— **At present, Van Herick's method is a standard technique used to screen a Narrow Anterior Chamber Angle (NACA) and Angle-Closure Glaucoma (ACG). It can identify a patient who suffers from NACA and ACG by considering the width of peripheral anterior chamber depth (PACD) and corneal thickness. However, the screening result of this method often varies among ophthalmologists. So, an automatic screening of NACA and ACG based on slit-lamp image analysis by using Support Vector Machine (SVM) is proposed. SVM can automatically generate the classification model, which is used to classify the result as an angle-closure likely or an angle-closure unlikely. It shows that it can improve the accuracy of the screening result. To develop the classification model, the width of PACD and corneal thickness from many positions are measured and selected to be features. A statistic analysis is also used in the PACD and corneal thickness estimation in order to reduce the error from reflection on the cornea. In this study, it is found that the generated models are evaluated by using 5-fold cross validation and give a better result than the result classified by Van Herick's method.**

## I. Introduction

This study is in the medical field, and involves some medical concepts including Glaucoma, Gonioscopy or Gonioscopic Examination, and Limbal Anterior Chamber Depth (LACD) Measurement estimated by using Van Herick's method.

### A. Glaucoma

Glaucoma has become a major cause of irreversible blindness. It is a group of diseases that can damage the eye's optic nerve. Also, it is normally associated with increased fluid pressure in the eye. These days, there are many techniques to detect glaucoma such as using the retinal or fundus image [1], Scanning Laser Polarimetry (SLP) [2], Confocal Scanning Laser Tomography (CSLT) [3], and Stratus OCT [4] to analyze the optic nerve and visual field. Glaucoma can be roughly divided into 2 main types: Open Angle Glaucoma (OAG) and Angle-closure glaucoma (ACG). Acute angle closure attack is one kind of ACG. Its symptoms are severe and dramatic because the angle closes suddenly. It can make patients have sudden painful visual loss with intraocular pressure of more than 30 mmHg. It may result in blindness within a few hours of its onset. Degenerating nerve fibers of the optic nerve is serious, therefore, early detection of the disease and prevention are necessary. People with NACA are more likely to develop ACG. If they get a laser treatment in the early developing stage, about 97% of them will not get the disease. Consequently, this study focuses on NACA and ACG screening.

ACG occurs when the fluid in the front part of the eye cannot reach the drainage area because the chamber angle gets blocked by part of the iris. It can cause a sudden build up of pressure in the eye, which can damage the optic nerve and result in vision loss. In people with a tendency to ACG, the anterior chamber depth is smaller than average; in other words, the anterior chamber angle is narrow.

### B. Gonioscopy

The current reference standard for assessment of the anterior chamber angle is Gonioscopy [5], this technique uses the goniolens in conjunction with a slit-lamp for visualization. Gonioscopy allows the ophthalmologist to view the front part of the eye (anterior chamber) to determine if the iris is closer than normal to the back of the cornea. This test can help diagnose closed-angle glaucoma.

### C. Van Herick's Method

Limbal Anterior Chamber Depth Measurement estimated by using Van Herick's method is one of the standard techniques used for screening patients who may suffer from ACG. It was developed as a non-contact approach for quick assessment of the lateral chamber angle. To perform this evaluation, a slit-lamp microscope is used. The illumination column of the slit-lamp is offset from the central axis of the microscope by 60 degrees to the temporal side. A bright, narrow beam of light is directed to the ocular surface at the limbus, as shown in Fig. 1. LACD measurement is performed by comparing the depth of PACD to the thickness of the cornea. The relation between the PACD and the corneal thickness can be found in [6]. If the chamber depth or gap between two light reflexes is smaller than a quarter of corneal thickness, or width of light reflex on the cornea, the chamber angle is dangerously narrow and an angle-closure is likely. Otherwise, the chamber angle is open and an angle-

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closure is unlikely. If no space is visible between two light reflexes, the chamber angle is closed and an angle-closure already exists.

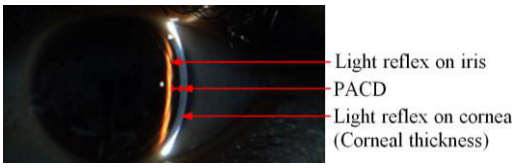



Figure 1. Slit-lamp image

The work by [7] studied a grading scheme for LACD measurement. It reports the specificity and sensitivity to be 65% and 99% in the case of using the grading scheme with PACD to corneal thickness at 25% (Van Herick's grading scheme), to be 86% and 84% for using a cutoff value at 15%, and to be 93% and 91% for using a cutoff value at 5%. This study reveals that a change of grading scheme can gain more specificity than Van Herick's scheme, but it gives a lower sensitivity. If it is operated by an automatic system or machine, it can easily adjust more resolution of the grading scheme in order to gain a better result. In addition, the result of this method comes from manual grading by an ophthalmologist. Variation of physician experience can make the accuracy of screening results variable among ophthalmologists [8]. Therefore, this study proposes an automatic screening of NACA and ACG based on slit-lamp image analysis by using Support Vector Machine (SVM) in order to improve the screening accuracy and avoid the error in the manual grading process. Although there are many classification techniques, SVM is selected for this study because it is suitable for binary classification and also consumes less computational time, compared to other techniques.

The paper is organized as follows: In Section II, system overview and methodology are described. In Section III, experimental results are discussed. Section IV draws a conclusion. Finally, Section V shows future work.

## II. METHODOLOGY

The flowchart of automatic screening of Narrow Anterior Chamber Angle (NACA) and Angle-Closure Glaucoma (ACG) based on slit-lamp image analysis by using Support Vector Machine (SVM) is shown in Fig. 2.

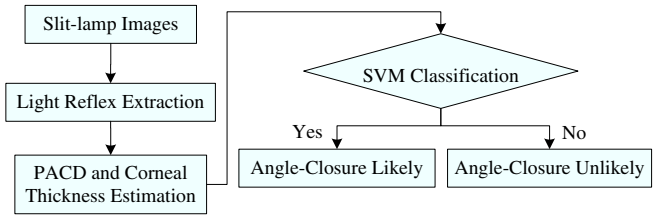



Figure 2. The flowchart of automatic screening of NACA and ACG based on slit-lamp image analysis by using SVM.

The system starts by getting a slit-lamp image, then, iris and cornea extraction are performed in order to measure the width of PACD and corneal thickness. Next, the width of PACD and corneal thickness are measured from various areas and estimated for the purpose of removing the outlier data and error from reflection on the cornea. These values are considered as features of slit-lamp images. Lastly, a result is classified by the trained model of SVM into an angle-closure likely or angle-closure unlikely.

### A. *Slit-lamp Image*

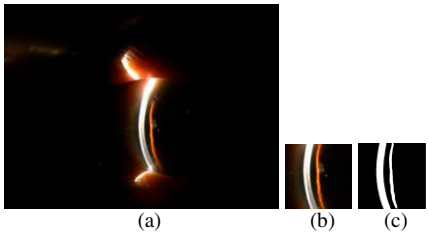
The slit-lamp images are captured from the slit-lamp microscope by an ophthalmologist. Their original size is 3,264 x 2,448 pixels, or 7,990,272 pixels. An example of angle-closure likely and angle-closure unlikely images are shown in Fig. 3. The angle-closure likely image shows the small gap between two light reflexes. Therefore, the width of PACD and corneal thickness are selected to be features in order to represent the characteristics of each slit-lamp image.

(a) (b)

Figure 3. The example slit-lamp images,
(a) Angle-closure likely and (b) Angle-closure unlikely

### B. *Light Reflex Extraction*

To extract features of a slit-lamp image, 2 light reflexes, i.e., light reflex on the iris and light reflex on the cornea are required to be extracted. The process starts by detecting the Region of Interest (ROI) (Fig. 4(b)). Then, the light reflex extraction function is performed (Fig. 4(c)). These details can be found in [8].



(a) (b) (c)

Figure 4. Light reflex extraction process (a) Input slit-lamp image, (b) ROI detection image and (c) Light reflex extracted image

### C. *PACD and Corneal Thickness Estimation*

In general, the measurement area, which can be used to grade the result, is the center position along vertical axis, which is shown as a red line in Fig. 5 (b). Nevertheless, some slit-lamp images may contain the reflection on the cornea. It will make an error appear in the light reflex extracted image. So, the width of PACD and corneal thickness are required to be estimated. The estimation process starts by dividing the area along the vertical axis of the iris into 5 areas. Area3 is identified as the center area as shown in Fig. 5 (a). Then, the width of PACD and corneal thickness are measured at 5 positions in one area. The mean value of PACD and minimum value of corneal thickness are calculated to represent the estimated values of that area. For Van Herick's method, the processing area is only Area3. But, to extract the features that will be used in the SVM model, all areas have to be processed. Therefore, the 5 measuring positions of each area are shown in Fig. 5 (c). Moreover, the difference area conducts the different shape of reflection. So, the estimation process is divided into 2 types.

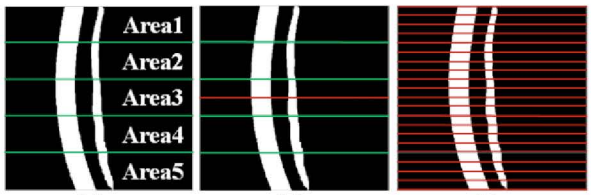


Figure 5. The PACD and corneal thickness measurement, (a) 5 measuring areas along vertical axis, (b) The measuring position of Van Herick's method and (c) The measuring positions of proposed method

- Area1 and Area5

  A simplified statistic analysis is performed on Area1 and Area5 in order to remove the outlier data from reflection on the cornea as shown in Fig. 6. The unacceptable value or the outlier can be described by (1). The outlier data will not be included in PACD and corneal thickness estimation, e.g., position2 is the outlier of Area1 in Fig. 6. Therefore, the measured values of position1, 3, 4, and 5 will be used in the estimation process, i.e., the minimum value of corneal thickness represents the estimation of corneal thickness and the mean value of PACD represents the estimation of PACD.

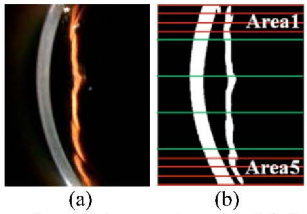


Figure 6. An example case that requires simplified statistic analysis (a) Input slit-lamp image and (b) Processed image

$$|x_i - \mu| > \sigma \tag{1}$$

where $i$ is a position number, and can be 1, …, 5
$x$ is the considered data
$\mu$ is a mean value in the considered area. It can also be written as:

$$\mu = \frac{\sum x_i}{5} \tag{2}$$

$\sigma$ is a standard deviation in the considered area. It can also be written as:

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{5}} \tag{3}$$

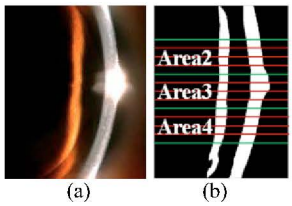


Figure 7. An example case of selecting minimum value of corneal thickness (a) Input slit-lamp image and (b) Processed image

- Area2, Area3, and Area4

  Commonly, the shape of reflection on the cornea occurred in Area2, 3, and 4 is the big white spot. For avoiding the error occurred from this reflection, the minimum value of corneal thickness and the mean value of PACD are selected to represent the width of PACD and corneal thickness of Area2, 3, and 4, respectively (Fig. 7.).

### *D. Training and Classification by Using Support Vector Machine (SVM)*

To train the SVM model, features of slit-lamp images and kernel function are selected to be input. Then, using 5-fold cross validation to evaluate the trained model by randomly assigning the data to 5 sets, 4 sets are used for training and 1 set is used for testing. Then, the testing set is changed until all data are tested to consider the classification accuracy of the model. After that, features and kernel function are changed. The evaluation is repeated until the model gives the best accuracy. Lastly, the deployment model is created by using all data with the same features and kernel function.

## III. Experimental Result and Discussion

The preliminary experiment was carried out at King Chulalongkorn Memorial Hospital by capturing slit-lamp images from 27 volunteers. There are 50 slit-lamp images that can be used for the experiment. After that, all volunteers were given a Gonioscopic examination, and this result was used as a baseline. To develop the SVM model, 5-fold cross validation was performed in order to evaluate the trained model. The most suitable features for this dataset are 10 features, i.e., the estimation value of PACD width and corneal thickness from 5 areas. The most suitable kernel function is linear. To compare between the result from Van Herick's method and SVM's, 50 slit-lamp images were processed from the first step to the PACD and corneal thickness estimation. Then, all slit-lamp images were classified by using Van Herick's method and the trained SVM model.

NOTE: There is 1 volunteer who has only 1 eye, and 3 other slit-lamp images cannot be graded because the volunteers have a plateau iris, pterygium, and peripheral anterior synechiae.

The classification results of the Van Herick's method are shown in Table I, and for the proposed method are shown in Table II.

The sensitivity (*SENS.*) is the percentage of true positive (*TP*) incidents of angle closure-likely. It can also be written as:

$$SENS. = \frac{TP}{TP + FN}, \tag{4}$$

where *TP* is an angle closure-likely correctly classified as angle closure-likely
*FN* is an angle closure-likely incorrectly classified as angle closure-unlikely

The specificity (*SPEC.*) is the percentage of true negative (*TN*) incidents of angle closure-likely. It can also be written as:

$$SPEC. = \frac{TN}{TN + FP}, \tag{5}$$

where *TN* is an angle closure-unlikely correctly classified as angle closure-unlikely
*FP* is an angle closure-unlikely incorrectly classified as angle closure-likely

TABLE I. TABLE OF CONFUSION OF VAN HERICK'S METHOD

| Gonioscopy Diagnosis by Ophthalmologist | Classified by Van Herick's Method: Likely | Classified by Van Herick's Method: Unlikely | |
|---|---|---|---|
| Likely | TP 3 6.0% | FN 5 10.0% | SENS. 37.5% |
| Unlikely | FP 2 4.0% | TN 40 80.0% | SPEC. 95.2% |
| | 60.0% 40.0% | 88.9% 11.1% | ACC. 86.0% 14.0% |

TABLE II. TABLE OF CONFUSION OF SVM MODEL

| Gonioscopy Diagnosis by Ophthalmologist | Classified by SVM: Likely | Classified by SVM: Unlikely | |
|---|---|---|---|
| Likely | TP 5 10.0% | FN 3 6.0% | SENS. 62.5% |
| Unlikely | FP 2 4.0% | TN 40 80.0% | SPEC. 95.2% |
| | 71.4% 28.6% | 93.0% 7.0% | ACC. 90.0% 10.0% |

For this dataset, the proposed method can improve the sensitivity and accuracy of screening result. It can reduce the FN that is more serious than FP, in medical data. The rest of the 3 FN images and TP images were investigated. To make it clearer to see the details of each eye, the brightness and contrast are adjusted as shown in Fig. 8.

(a) (b)

Figure 8. The example images with brightness and contrast adjusted (a) FN image and (b) TP image

The pictures reveal that the distance between the limbus and the light reflex on the cornea of FN and TP images are different. All FN images have a longer distance than TP images. But the projected position of slit-lamp has to be near the limbus as much as possible. This problem frequently occurs in manual operation by humans. The next phase of the automatic NACA and ACG screening system should take this parameter into account to be a feature for training the SVM model. Furthermore, to evaluate the true performance of the system, number of TP images should be increased to balance off number of TF images, then, it may gain a better result of the sensitivity and accuracy.

## IV. CONCLUSION

The proposed automatic screening of angle-closure glaucoma by using support vector machine provides acceptable screening results. It can also improve the sensitivity and accuracy if compared to the traditional method. Currently, the best classification model from this dataset is created by using the linear kernel function. It also uses the width of PACD and corneal thickness from many areas as features. Furthermore, to improve the PACD and corneal thickness estimation function, the simplified statistic analysis is used in order to remove the outliers, and a minimum value is used to avoid the error from reflection.

## V. FUTURE WORK

To improve the accuracy of automatic NACA and ACG screening system by using SVM, the algorithm has to be developed to extract and measure the distance between limbus and light reflex on the cornea, then, consider this value as an additional feature of a slit-lamp image. Moreover, the human error in a manual operation of a slit-lamp microscope can also be eliminated by developing an automatic machine with automatic limbus detection function for controlling the position of microscope and slit-lamp. A larger dataset is required in order to improve the accuracy of the classification model for implementation.

## ACKNOWLEDGMENT

This research is financially supported by Thailand Advanced Institute of Science and Technology (TAIST), National Science and Technology Development Agency (NSTDA), Tokyo Institute of Technology, Sirindhorn International Institute of Techcnology (SIIT), Thammasat University (TU), and the National Research University Project, Thailand Office of Higher Education Commission. The author would like to thank King Chulalongkorn Memorial Hospital for supporting us with medical advice and data.

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