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The Achievement of Various Shapes of Specular Reflections for Cataract Screening System Based on Digital Images

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Abstract. The use of image processing techniques in early detection of cataracts is a promising method to overcome the problems about limited health facilities in developing countries. This method used three kinds of features; specular reflection appearance, texture uniformity and average intensity inside the pupil. Refers to the some characteristics of reflection; the core of this method is based on a specular reflection appearance inside the pupil. Based on the reflection theorem, normal eye images will have two kinds of reflection inside the pupil while cataract eye images have one reflection and both of them are always in a line so we can easily distinguish between cataract and normal eye images. Refers to the use of specular reflections, there is a consideration that the shape of specular reflection is a circle only, while in fact there are many different shapes and sizes of specular reflections inside the pupil. In this paper we will focus on the consideration about the shapes of specular reflections for cataract screening such as an ellipse, circle, cube and rectangular. The result shows that assumption about ellipse as a shape of specular reflection will give best performance for cataract screening than others shape assumption.

Keywords: cataract screening, specular reflection, shape of reflections, limited health facilities

1. Introduction

Cataract is a kind of eye disease [1]; that is a clouding in the lens of the eye that affects vision. Cataract exhibits a lot of whitish color inside a pupil. The three classes of cataracts are immature, mature and hypermature, which differ in seriousness. In an immature cataract, a whitish color appears inside the pupil but less so than in mature or hypermature cataracts. Usually, the condition is not yet serious. A Hypermature cataract exhibits much whitish color inside the pupil and can cause the lens of the eye to break if surgery is not carried out. This condition is very dangerous. Figure 1 shows examples of the range of serious and non-serious conditions.

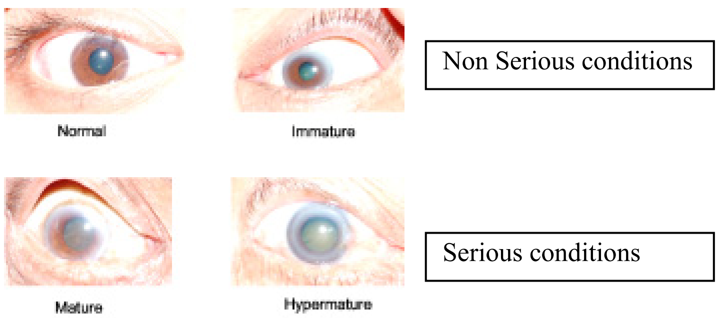

Figure 1. Example of eye images

The World Health Report published in 2001 estimated that there were 20 million people who are bilaterally blind (i.e., with eyesight of less than 3/60 in the better eye) whose blindness was caused by age related cataracts [2]. That number will have increased to 40 million by the year 2020. Increasing age is associated with an increasing prevalence of cataracts, but in most developing countries, cataracts often occur earlier in life. One of the developing countries that has the highest number of people with cataracts is Indonesia. There are about 6 million people in Indonesia who suffer from cataracts, but Indonesia only has about 750 ophthalmologists for a population of more than 200 millions people (one for every 350.000 people). In addition, ophthalmologists are not evenly distributed. Many ophthalmologists are located in the capital city, yet many people have no access to ophthalmologists because of geographic conditions. In order to solve the problems about cataract diagnosing in developing countries, there are few studies on the diagnosis of cataract using simple equipment conducted by Supriyanti [3], [4], [5], [6], [7]. Supriyanti in her research [3], [4] using information about specular reflection inside a pupil for getting a characteristic between serious and non-serious condition of cataracts. She got a clear characteristic about serious and non-serious conditions of cataracts using specular reflection appearance inside the pupil. However, in this research she used limited data, therefore it need to be applied in more and varied types of data. In order to improve the performance of cataract screening system, in her research [5], [6], she added texture analysis for getting more characteristics of serious and non-serious conditions. Also, this research applied in more and various types of data. The performance of using specular reflections and texture analysis for cataract screening is promising. There are TPR (True Positive Rate) about 92% and FPR (False Positive Rate) about 18%. Although all research conducted by supriyanti [3], [4], [5],[6], [7] using specular reflections and texture analysis, actually the core method of this system is specular reflections appearance inside the pupil. Specular reflecftion is the mirror-like re°ection of light from a surface, in which light from a single incoming direction is reflected into a single outgoing direction. The use specular reflection analysis as the core of this method, because the characteristics of specular reflection is not depend on illumination conditions. The main characteristic is the intensity of specular reflection always higher than the intensity in the surrounding area. However; in her research above, she considered that the shape of specular reflections is a circle only, while in fact, specular reflections have many different shapes. Therefore, in this paper we emphasize on the consideration about various shapes of specular reflections to be used in cataract diagnosing.

2. Proposed Method

2.1. Specular Reflection Analysis

As discussed by Supriyanti [3], [4], algorithm for analyzing specular reflection refers to the working principles of ophthalmoscope and slit lamp. Light hits the frontal surface of the lens and makes a reflection called frontside reflection. But actually light also hits the rear side of the lens. For a non serious condition, there is not a whitish color inside the lens so it will be reflected again, which is called backside reflection. For a serious condition especially, because there is a lot of clouding in the lens, light will not be reflected again; therefore we got characteristics of both conditions. For non-serious conditions there are two reflections appear inside the pupil, while for serious conditions there are only one reflection appear inside the pupil.

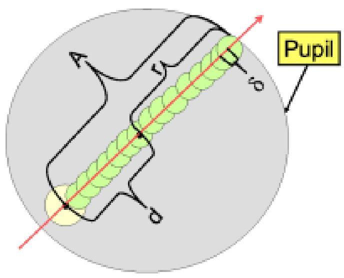

Figure 2. Searching backside reflection area data

We conducted a search to find the backside reflection, as depicted in Figure 2. Using the coordinate of the center and the radius of the frontside reflection, we then searched for the backside reflection by searching for areas of higher intensity beside the frontside reflection compared with their immediately surrounding areas in a line that expressed by Equation 1.

$$A = (d+r) - \delta \quad \ldots\ldots (1)$$

where A is the length of backside reflection searching, d is the distance between the center of pupil and the center of the frontside reflection, r is the radius of the pupil and δ is the radius of the backside reflection. As described in Figure 2, while searching intensity along line, we assume that specular reflection always has a circle shape. In fact, the shapes of specular reflections are varied as described in Figure 3. As shown in

Figure 3, some variations of the specular reflections shape are circle, cube, rectangular and ellipse, although we used the same flash light during taking photographs. Therefore, during searched for backside reflections area as described in Figure 2, we considered to assume various shapes of specular reflections and did intensity searching based on the shape that we assumed before as shown in Figure 4.

We apply Equation 1 which the value of δ is determined by following the assumption of specular reflection as shown in Figure 5.

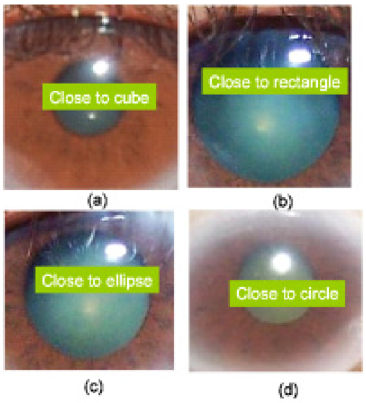

Figure 3. Various shapes of specular reflections inside the pupil

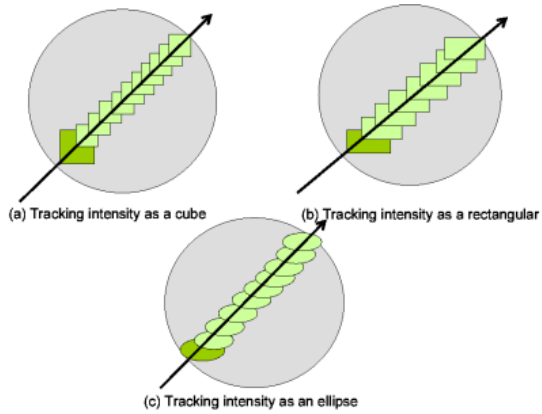

Figure 4. Intensity tracking using various shapes of specular reflections

Then, we compare the performance of each shapes of specular reflections in order to provide a recommendation on the tendency of specular reflection's shape that can give the best results for cataract screening sis we apply an equation as discussed by Supriyanti [3] and described in Equation 2.

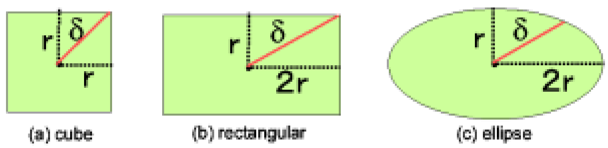

Figure 5. The size using for intensity tracking

$$P_n = \frac{P}{n} \qquad (2)$$

where P is the numbers of points that have increasing intensity value and n is the numbers of points along an intensity tracking line. The main characteristic of serious and non-serious conditions depends on the presence of backside reflection in an image that is shown by increasing intensity in an area during intensity searching as described in Figure 2.

2.2. Statistical Texture Uniformity

2.2.1. Uniformity

As discussed by Supriyanti [5] [6], although specular reflections analysis had a good performance as a cataract screening method based on digital images, but she also exploit texture analysis method in order to improve the performance. In this part, Supriyanti [5] [6] exploit uniformity and average intensity. Uniformity will be maximizing when all gray levels are equal. Whitish colors inside the lens have two kinds' distributions. First, whitish color spread smoothly inside the pupil. In the early stage, this kind of cataract has a thin layer of whitish color and covers the whole lens surface gradually until the whitish color layer becomes thick. Second, whitish color spread uneven inside the lens. It will appear a coarse texture inside the pupil. Almost all non serious conditions have a smooth texture with a high value of uniformity.

2.2.2. Average Intensity

As discussed by Supriyanti [6] average intensity computed by measuring average intensity inside the pupil. Averaging would be accomplished by summing the gray levels inside the pupil region and dividing by the total number of pixel inside the pupil. It will be very simple intuition that cataract eyes have brighter intensities than normal eyes.

2.3. Diagnosing by Classification

Extraction features inside the pupil including specular reflection appearance and statistical texture that consists of uniformity and average intensity as discussed in [3], [4], [5], [6], [7]. First we did specular reflection analysis by measuring the value of P_n. We did many assumptions about the shapes of frontside reflections. First we assume that the shape is a circle, second we assume that the shape is a cube, third is a rectangular and the last we assume that the shape is an ellipse. Also we measure the uniformity and average intensity in the pupil. For identifying between serious and non-serious conditions we use a Support Vector Machine (SVM) classifier because SVMs are powerful machine learning methods for both regression and classification techniques. We use Gaussian Kernel to transform the input data to high-dimensional space where the problem is solved. To build the system, we used Matlab R2007B with image processing toolbox. Also, for building a classifier to classify between serious and non-serious condition, we use SVM toolbox was developed by Canu [8]. To test the performance of our system, we use several parameters. The first is True Positive Rate (TPR). TPR determines a classifier or a diagnostic test performance on classifying positive instances correctly among all positive samples available during the test. The second is FPR (False Positive Rate). FPR, on the other hand, defines how many incorrect positive results occur among all negative samples available during the test [9]. We only use TPR and FPR parameters because these parameters are sufficient to represent the accuracy of a system.

3. Experimental Results

All data used in these experiments were acquired from Indonesia. Especially, for cataracts data were taken from Kamandaka Eye Clinic. First we use a variety of types and brands of digital cameras for acquiring data. Types and brands of digital cameras used are Nikon Coolpix L12, Nikon D40X and Canon IXY Digital 820IS. These kinds of digital cameras have different characteristics. The Nikon Coolpix L12 is a very simple digital camera. Even for a point and shoot type model it has a reduced set of features that make it easy to use. The Coolpix L12 has seven mega pixels and a three times zoom lens. The Nikon D40X is a digital SLR camera with facility more complete than Nikon Coolpix L12. It has 10.2 mega pixel and a new telephoto AF-S DX Zoom-Nikkor 55-200mm f/3.5-5.6G VR ED zoom lens. The Canon IXY Digital 820IS is also a very simple digital camera that has 10 mega pixels. Data was taken by an amateur photographer using all kinds of digital cameras; therefore each data was taken for three times using different cameras above. We conclude that the performance of each camera is almost the same and promising as main equipment for detecting cataract under limited health facilities. In another words we also can recommend that we can use any type and brand of digital cameras for using our system. Although we get the results that basically we can use different types of digital cameras in our system, but in fact digital cameras have different shape of flash light, while the flash light is an important part of digital camera to produce specular reflections which is the core of our method. The next step we tried to investigate whether the shape of the specular reflections always same with the shape flash light or not, so we did experiments by using one type of digital camera cover the flash light with aluminum foil that has been given the holes with various shapes such as cube, ellipse, circle and rectangle. The result shows that the shape of specular reflections not always same with the shape of the hole attached in flash light. According to the shapes of reflections, then we investigate the trend shapes of specular reflections and measure which the shape will give the best result for cataract screening. We did an intensity tracking refers to the Figure 2 and change the shape of frontside reflection as an circle, cube, rectangular and ellipse as described in Figure 4. Figure 6 shows the result of performance each shape of specular reflections. It seemed that all shapes have performance that almost evenly, although ellipse gives the best result than others.

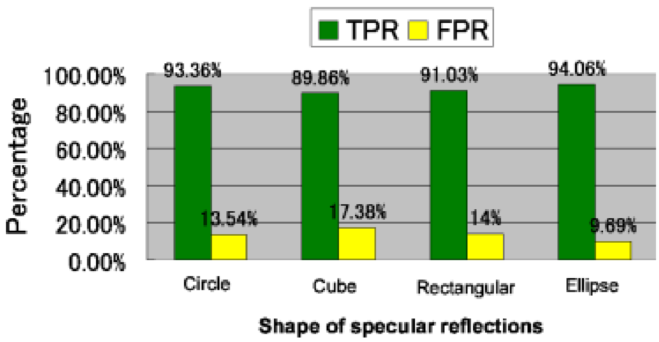

Figure 6. The performance of various shapes of specular reflection

4. Conclusions

Basically, in order to do specular reflection analysis for cataract screening we can assume various shapes of specular reflections inside the pupil. However in this case, in order to get a best result we recommend use an ellipse as an assumption of the specular reflection's shape.

5. Acknowledgment

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