# Extracting Appearance Information inside the Pupil for Cataract Screening

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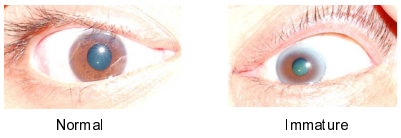
## Abstract

*In this paper, we propose a method for cataract screening. Referring to the fact of increasing number of cataract especially for the people who lived in the developing countries, this kind of discussion will be important. The method used three kinds of features; specular reflection appearance, texture uniformity and average intensity inside the pupil. Actually, The core of our method is based on a specular reflection appearance inside the pupil. Referring to 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. However, some times we face the problems of distinguishing specular reflection and whitish color caused by serious cataracts. It will cause a misclassification that a serious cataract are regarded as a normal. In this paper we propose an improved method for handling such kind of problems by extracting statistical texture consists from an uniformity and an average intensity inside the pupil. The result shows that percentage value of True Positive is* 91.97% *and percentage value of False Positive is* 18.75%. *This performance is good enough for cataract screening especially in the developing countries.*

Keywords : cataract screening, specular reflection, statistical texture, uniformity, average intensity

## 1 Introduction

Cataract is a kind of eye disease [1]; that is a clouding in the lens of the eye that affects vision. Cataract exhibit 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. Hypermature cataracts 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. 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.




(a) Non-serious condition


(b) Serious condition

Figure 1: Example of eye images

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 eye doctors for a population of more than 200 millions people (one for every 350.000 people). In addition, eye doctors are not evenly distributed. Many eye doctors are located in the capital city, yet many people have no access to eye doctors because of geographic conditions.
There is much related research about diagnosing cataract. For example, Sugata [5] examined normal and cataract lenses and suggested the possibility of diagnosing by measuring the attenuation characteristic of the lens. Biwas [6] discovered the role of catalin in the prevention of posterior capsular opacification (OPA) while conducting an experimental study on rabbits. Garif [7] applied speckle technologies and measured retinal angular resolution by laser retinometry at the stage of preoperative cataract diagnosis. It appears all research above was devoted to eye specialists who usually used special equipment requiring training and some knowledge about cataract. Those studies are valuable if implemented in conditions where there are enough eye doctors and health facilities are equally distributed, otherwise condition is quite difficult to implement all researches above. Supriyanti et al. [3] proposed a cataract screening system dedicated to developing countries or rural areas where eye doctors and health facilities are limited. The re-

search developed a simple method for cataract detection using low-cost and easy-to-use equipment; also the system can be used by anyone and anywhere. The method diagnosed cataract automatically based on specular reflection appearance inside the pupil image. The specular reflection appearance method developed by Supriyanti [3] had good performance distinguishing between serious and non-serious conditions. However when implementing this system with real patients, there were sometimes problems distinguishing between serious and non-serious conditions. It caused by some reasons. First, there were sometimes problems distinguishing between whitish color backside reflection therefore a serious condition is diagnosed as a non-serious condition. Second, when the backside reflection [3] is too small or too weak, a non-serious condition is diagnosed as a serious condition. To handle these problems, we propose a screening method which exploit information inside the pupil including specular reflection appearance and statistical texture consists from uniformity and average intensity as presented in Figure 2. In this paper, we discuss a method

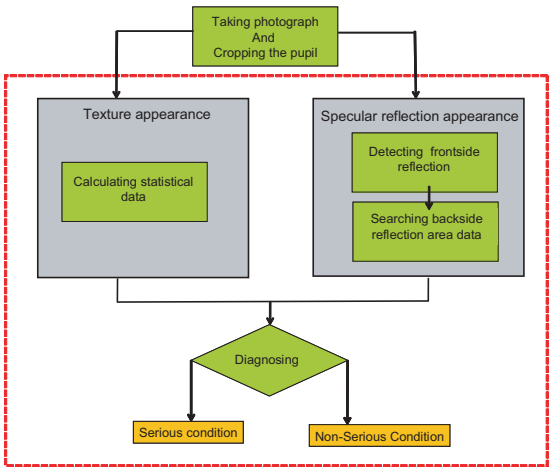



Figure 2: Screening flow chart

for measuring specular reflection appearance and statistical texture including uniformity and average intensity as presented in the red-box in Figure 2. We use all features based on the following reasons. First, we can detect specular reflection under uncontrolled illumination conditions because this area always brighter than the surrounding area inside the pupil. Second, distribution of whitish color for some serious conditions are uneven so we can exploit an uniformity inside the pupil. Third, we exploit an average intensity features inside the pupil. This refers to the fact, although the uniformity for both conditions are similar, in the serious condition it is caused by whitish color spreading evenly while for a non serious condition there is no whitish color. This conditions will affect to the average intensity inside the pupil. Although we assume that the pupil area in a given image is already detected by human operation or by automatic image processing, to get a sufficient input image, Supriyanti [3] already discuss some considerations to take photographs using a portable digital camera.

# 2 Proposed Method

## 2.1 Specular reflection analysis

We develop our algorithm refer to the working principles of opthalmoscope and slit lamp. An ophthalmoscope is an instrument that enables a doctor to examine the inside of a person's eye. The instrument has an angled mirror, various lenses, and a light source. A slit lamp is an instrument that enables a doctor to examine the entire eye under high magnification and that allows measurement of depth. The slit lamp focuses a bright light into the eye. Both equipments have a similarity for diagnosing cataract. They utilize a light to examine the opacities inside the lens. Figure 3 describes the

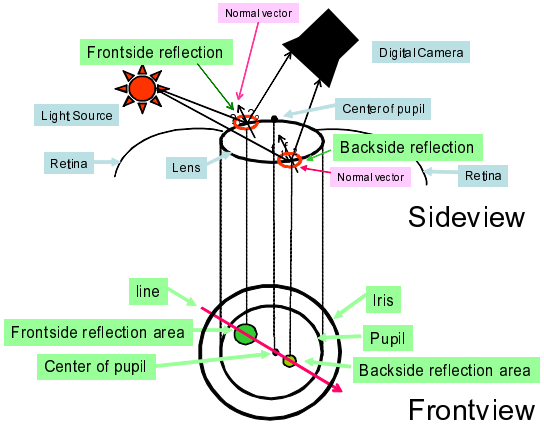



Figure 3: Model of reflection characteristic in eye

principle work of the specular reflection method [3]. 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. The different characteristics are shown in Figure 4. Based on the reflection theorem, the direction of the normal vector always goes to the center of the pupil, so when we look at the image appearance we can find the relationship of the location between the two reflections and the center of the pupil; they are on a single line.

In order to implement this method, First we have to detect frontside reflection. The detailed algorithm for detecting frontside reflection already discussed by Supriyanti [3].

Second, using the relationship between both reflections, we conducted a search to find the backside reflection, as depicted in Figure 5. 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

$$A = (d + r) - \delta \tag{1}$$

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


(a) Non-serious condition (b) Serious condition

Figure 4: Example of reflection appearance

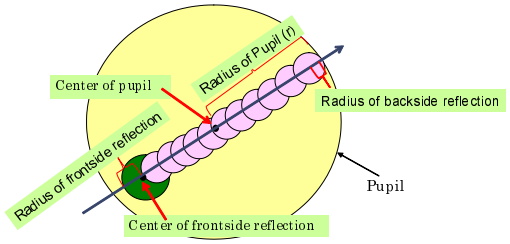



Figure 5: Searching backside reflection area data

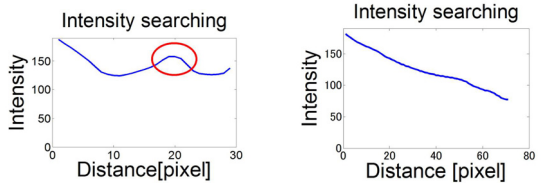
pupil and $\delta$ is the radius of the backside reflection. Based on the result of intensity tracking as shown in Figure 5, we implemented a differential function in a discrete system to develop an automatic screening between the serious condition and non serious condition based on the intensity tracking result that is expressed by Equation 2.

$$D = I(S) - I(S-1) \tag{2}$$

where $I$ is intensity and $S$ is a distance between the center of the frontside reflection and the next circle that will be investigated. During intensity searching, if $D(S)$ >0 it means there is an increasing intensity value. Otherwise, if $D(S)$ <0 it means there is a decreasing intensity value. Based on the discussion by Supriyanti [3], a non serious condition is always have a great increasing intensity that indicated existence of backside reflection. Because we have variations of the numbers of intensity searching, we define the normalized number of increasing value determined by Equation 3.

$$P_n = \frac{P}{n} \tag{3}$$

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. Figure 6 shows the examples of the result of intensity tracking for serious and non-serious.




(a) Non-serious condition (b) Serious condition

Figure 6: Analyzing backside reflection

## 2.2 Statistical texture analysis

### 2.2.1 Uniformity

An important approach to region description is to quantify texture content. In statistical texture analysis, the descriptor measures properties such as smoothness, coarseness and regularity. Basically, there are two kinds of textures inside the pupil; smooth and coarse. This can be calculated by the uniformity value expressed in Equation 4. Where $U$ is the value of uniformity, $H$ is probability histogram of the intensity levels in a region, and $N$ is the number of pixel in an image, Let $i = 0, 1, 2, \cdots, L-1$, be the corresponding histogram, where $L$ is the value of possible intensity. Uniformity will be maximum when all gray levels are equal. Whitish color 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.

$$U = \sum_{i=0}^{L-1} \left( \frac{H(i)}{N} \right)^2 \tag{4}$$

### 2.2.2 Average intensity

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. The equation to measure an average intensity expressed in Equation 5, where $m$ is the mean (average) intensity, $I$ is the possible intensity, and $N$ is the number of pixel in an image . It will be very simple intuition that cataract eyes have brighter intensities than normal eyes.

$$m = \sum_{i=0}^{L-1} \left( \frac{I(i)}{N} \right) \tag{5}$$

## 2.3 Diagnosis by classification

We extract features inside the pupil including specular reflection appearance and statistical texture that consists of uniformity and average intensity for handling problems arises from research by Supriyanti [3] about specular reflection analysis for cataract screening. When the whitish color is located in the searching line during intensity searching, it makes the value of $P_n$ for the cataract eye image become higher than usual and the system will judge that this is a non serious condition. It is an important problem for our system even though so far this kind of case has not occured often. On the other hand, the spread of whitish color inside the pupil is uneven. This means that an uniformity inside the pupil is low. Based on this fact, we consider using information about texture uniformity inside the pupil for analyzing texture. Another problems occured when a non-serious condition diagnosed as a serious condition caused by the backside reflection is too small or too weak. To handle this problems, also we consider

using an average intensity inside the pupil. The experiments show that the average value of $P_n$ for non serious condition is 0.1832 with the average value of uniformity ($U$) is 0.0174, while for serious condition, the average value of $P_n$ is 0.0639 with the average value of uniformity ($U$) is 0.0135. We implemented this considerations into the image which has a value of $P_n \geq 0.1832$ and $P_n \leq 0.0639$, also for the image which has value of $U \geq 0.0174$ and $U \leq 0.0135$. Figure 7 shows the example data of three parameters between two classes serious and non serious condition that have values as discussed above including ; specular reflection appearance measured by Equation 3 and presented as a x-axis entitled backside reflection availability, the uniformity measured by Equation 4 and presented as a y-axis entitled uniformity,and the average intensity measured by Equation 5 and presented as a z-axis entitled average intensity. The Figure shows that between serious and non-serious condition are separating clearly.

In order to develop an automatically system, we use

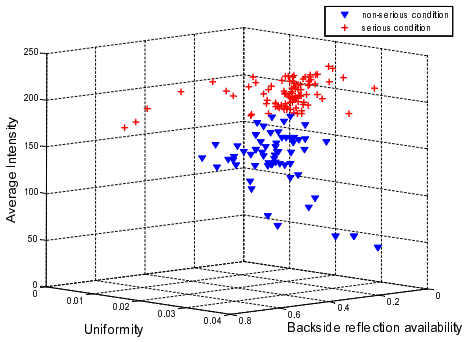



Figure 7: Example data of three parameters

a Support Vector Machine (SVM) classifier to separate between serious and non-serious conditions 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.

## 3 Experimental Result

We tested our system on 217 images taken in Indonesia. Based on diagnosis by an eye doctor, there were 137 images of serious conditions and 80 of non-serious conditions. Images were taken using a Canon IXY D820IS. To build the system, we used Matlab R2007B with image processing toolbox and SVM toolbox [8]. In order to make a cross validation for our method, we did evaluation several times until all data were evaluated. Figure 8 shows a summary of performance for each method. The result shows that current method has a good performance than other method. It presented by the percentage value of $TP$ and $FP$. Regarding the conditions in the developing countries which have limitations both of eye doctors and health facilities, implementing this method for cataract screening is sufficient.

## 4 Conclusion

Based on the performance of our method, it is promising for implementing into real condition as in

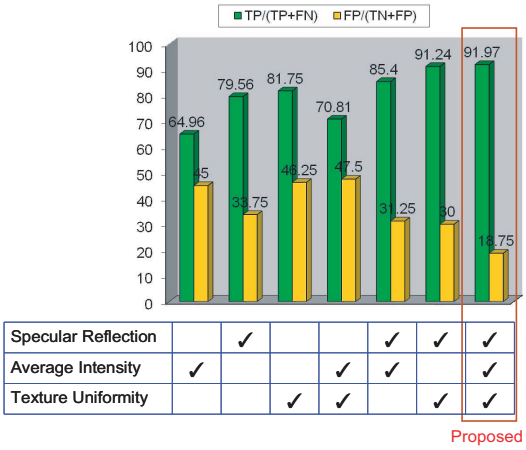



Figure 8: Performance comparison of each method

the developing countries or rural area. Although there are some error classifications, but basically it's sufficient for implementing in the real condition. Further research will involve developing automatic pupil detection because in the current research we still use the assumption that our input image is the pupil area only.

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