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Quantification of the overlapped Glistening in Intraocular lens

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Abstract
After cataract surgery, Intraocular (IOL) lens is implanted in human eye. When the IOL lens is in an aqueous environment, glistenings, fluid-filled microvacuoles are formed within an IOL. Glistening quantification is required to assess the quality of the lens and also to assign appropriate treatment. We proposed a novel technique to detect glistening region of IOL image and quantify them in a previous work. However, it has a limitation with the counting of glistening because some of them may be overlapped, closed or touched with glistenings in other region. In this paper, we applied watershed algorithm to calculate skeleton by influence
zones and used it to separate glistenings blobs. The result shows the proposed method can automatically accurately separate glistenings in normal IOL image.

**Keyword:** Image separation, watershed, glistening detection, medical image processing

1. **Introduction**

After cataract or refractive lens surgery, a lens, called intraocular lens (IOL), implants in the eye to replace the crystalline lens of the human eye [1]. Glistenings, fluid-filled microvacuoles, appear in the intraocular (IOL) lens when IOL is in an aqueous environment [2]. It increase forward light scatter which can effect human vision [3, 4, 5]. Previous work [6] we proposed software for quantification of glistening which could accuracy detect glistening. It was designed to semi-automatically detects glistening, computed glistenings properties and displayed result on the screen. However, this software still has limitation with compute number of glistening. Overlapped, touch and closed Glistenings were defined in one region, so, number of glistenings were counted only one glistening instead of actually number. Image segmentation is a basic issue in field of image processing [7, 8]. Its role is to segmenting the image into different feature of region [7] or dividing an image into distinct regions, mainly corresponding to interested objects in a background [9]. The watershed algorithm, based on the morphological principles, is a well-known image segmentation approach [9]. It segments image by find dividing lines [10]. This dividing lines is work like watershed which outlines each outer catchment basins which is local minimum value within image [10]. The watershed approach certifies boundaries on the image plane to be connected and closed, and each gradient at least corresponds to one area [11]. However, it exist some drawback because of noise sensitivity, it yield over-segmentation as each local minimum will form a catchment basin [9, 11, 12, 13]. Many methods are proposed to solve over-segmentation problem such as marker image [9], gradient transformation, multi-scale gradient and distance transformation [10], anisotropic filter [9], adaptive threshold [13], and marker-controlled watershed [14].

However, various kind of watershed technique cannot use in glistening detection technique because in image one glistening consist of 2 parts which are light region and dark region because of it curve reflex the light.

According to capability of watershed technique, in this paper, we applied watershed algorithm to calculate skeleton by influence zones to separate glistenings. It can automatic separate overlapped, closed and touched glistening after glistening detection algorithm is processed. The proposed method can increasing performance of glistening detection technique in numerical field.

The rest of this paper is organized as follows. Section 2 briefly presents the glistening detection method. Section 3 introduces watershed algorithm. Section 4 describes the
proposed method. The experiment result is shown in section 5. Conclusion is given in section 6.

2. Glistening Detection Method

Glistening detection was developed from blob detection and exudate detection [6]. Glistenings appear like blobs in IOL lens. Glistening detection has 6 steps to proceed consists of pre-processing, edge detection, connect broken lines and fill holes, border hardening, candidate classification and candidate selection. Its flowchart shown in Fig. 1.

Normally, input image is RGB color space and has difference size and quality. Firstly, we changed input image size to the suitable size. Then, Red channel is extracted from the RGB image because glistening has a good respond in a Red channel for the RGB color model. Sobel filter is employed in this step. It mainly use for glistening edge detection. We use both horizontal and vertical direction of sobel window to detecting edge of glistening and then combine it together. However lines from sobel filter can be broken because of weak edge. To connecting lines we using methodology called dilation operation. After we get edge of glistening, we fill all holes of every detected edge. We then repeatedly use dilation operation for one more time to straighten the boundary. Now, all glistening seem to be detected but its boarder still irregular. Erosion operation, using the same mask as dilation operation, is employed to smoothen boarder and decrease thick boarder which comes from dilation operation to make real size. Then, we erased all noise by deleting region whose size is unbelievable. All process is repeated in various threshold value to detect all glistening in IOL image. The result of each threshold value is combined in one image. This is a final step of glistening detection method. Result from glistening detection algorithm is binary number shows in fig. 2. Fig.2 (a) is example of IOL input image and Fig.2 (b) shows result of glistening detection whereas white regions are detected glistening and black region is background.

Glistening detection have a good performance to detecting glistening. However, the result from glistening is the white area of all glistenings. So, overlapped, touched and closed glistenings are shown in only one region. When the program calculates number of glistening, it cannot accuracy count number of glistenings.
3. **Watershed algorithm**

Watershed segmentation algorithm based on mathematical morphology is well known image segmentation approach [9]. Its idea comes from geography which is the gray value of each pixel presents the altitude while every local minimum value and its affecting regions represent basins [15]. This algorithm starts with slowly fill water to the basin. When two or more basins water will be melt, dam, which is watershed line, will be built between the basins to dividing it. It finishing when all basin already have dam surrounded.

![Fig. 2. Result of glistening detection technique](image)

Normally, watershed algorithm usually leads to over-segmentation because of sensitivity with noise. Marker-controlled watershed segmentation has been presented to be a strong and flexible method for segmentation of objects with closed contours [14] to overcome this problem. It was designed to erase noise by marking region or pixels before normal watershed algorithm processes. By the marker-controlled technique, unmarked region will not become to local minimum value, so the number of foreground mark will be the same as watershed region. However, marker-controlled watershed still followed over-segmentation in glistening...
image. So, in this paper, watershed algorithm is used to compute skeleton by influence zones which will explain in section 4.

4. Proposed Method

In this paper, we apply glistening detection technique and watershed technique to separate glistenings. The overall process was given in Fig. 3. It mainly compose of 4 steps, including pre-processing, foreground extraction, watershed algorithm and combine result. Original glistening detection result is used to in the last step to revise result. Separated glistening result of proposed technique is binary image as same as glistening detection result.

4.1 Pre-processing

In pre-processing process, the image is changed into grayscale image for preparing image. Background of IOL image always has difference color because of light. To make a high performance algorithm, we resized all image to 750 pixel of width and divided it into several small image to get difference gray level of each zones. So, every image is divided into 25 images. Size of it is the same.

4.2 Foreground extraction

Foreground marking is the step to marker object region for compute skeleton of glistening. Otsu thresholding technique is employed in this step. Basically, glistening within IOL image shows both darker region which are shadow of glistening and brighter region which reflected the light. Otsu thresholding technique can detect darker region or brighter region in IOL image. It depends on the intensity of gray value of the background image. However, extracted area should be white. So, after Otsu glistening method is processed, the proposed method check which region is detected. If detected region is darker region, all pixel is converted, 0 pixel changes to 1 and 1 pixel changes to 0. Fig.4 (a) and (c) are original IOL images. Fig.4 (b) and (d) shows result when Otsu method detected darker region and brighter region, respectively. To check which region was detected, first we calculated the number of white region. If white region has only one than, we compute the major-axis and minor-axis of white area and the major-axis and minor-axis of image. If both area are similar, ±5 pixels, we converted image.
4.3 Watershed Algorithm

Now, we already extracted foreground area from image. Glistening in IOL image consist of 2 parts, brighten area which come from the light reflection and darken area which is the shadow of glistening. So, if marked-controlled watershed algorithm is directly used, the result will be over-segmentation. This technique is developed for improve performance of glistening detection in numerical part. So, instead of using watershed algorithm to separated glistening, watershed algorithm is used for compute skeleton by influence zones of glistening to avoid over-segmentation. The watershed algorithm is employ with result in previous step. Result of watershed ridge lines represent border of glistening. Fig. 5 (b) and (d) shows the example of watershed ridge line and fig. 5 (a) and (c) are original IOL images.

4.4 Combine result

Combine result process works with 2 results, glistening detection algorithm and watershed algorithm process. From glistening detection process, we can get the glistening region. All white areas are detected glistenings and black region is background as shows in fig.1 (b). Watershed ridge lines are black lines. Thus, Eq. 1 is operation between glistening detection
image result and watershed algorithm result. Whereas, GD is the glistening detection result and WT is the watershed algorithm result. So, using eq. 1, we can use lines from watershed algorithm process to dividing both overlapped glistening and touch glistening.

\[ \text{Separated glistening} = WT \land GD \]

(1)

5. Experiment Result

The proposed method result is shown in table 1. It shows the compared result of both method, glistening detection and the proposed method. 1\textsuperscript{st} Column shows the IOL original input image, 2\textsuperscript{nd} Column shows the results from the glistening detection method and 3\textsuperscript{rd} Column shows the result from the proposed method.

From table 1 we can see that most of glistening is separated in case of the normal image which have similar color in background in 1\textsuperscript{st} and 2\textsuperscript{nd} row. In case of the 3\textsuperscript{rd} row, we can see that the glistening is separated in only a half of image because the background of the image is gradient so just some of glistening is separated. 4\textsuperscript{th} row shown that the proposed method still have over-segmentation problem in case of image is hard to separate glistening although using human eyes.

To evaluate the proposed method with stable background, 3 IOL images, which have overlapped glistenings, are used. Those images have a stable background and has overlapped touch and close glistening. Thus, it is used to evaluate the performance of the proposed method. First, each image and its ground truth image is divided into 25 images with the same size. Then, the number of glistening is count. The result show that the accuracy of glistening detection method have accuracy 78.36% in term of numerical while the accuracy of the proposed method have accuracy 87.39%.
Table 1. Comparing result of Glistening Detection and Proposed Method

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<th>Proposed Method</th>
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6. Conclusion

We have presented an improved glistening counting technique which applied watershed transform algorithm on glistening detection result. Glistening detection based on blob detection was applied first and then skeleton were computed by using influence zones from watershed algorithm. This process can roughly separate the overlapped glistening for the counting purpose. The result shows the proposed method can accurately segment glistening in case of good quality of image with accuracy 87.39%.

In our future work, we will improve the foreground extraction process so that it can be more accurate even with the unstable background.

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8. References


