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Software for Quantification of Glistenings on Intra-Ocular Lenses

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Abstract— An intraocular lens (IOL) is implanted in the eye after a cataract surgery. When IOL is in an aqueous environment, glistenings that are fluid-filled microvacuoles are often observed. Previously, studies of glistenings involved tedious work of manual glistenings labeling and rough estimation of glistening distribution. This paper proposes a software that can be used for automatic glistenings detection. The software evaluates glistenings appearance in lens, separating IOL lens into 3 zones and accurately compute average, density and validation to assist the user. The results are compared with clinician's hand-drawn ground truth for validation. The proposed GUI front-end is easy to use and very suitable for users who want accurate and quick glistenings detection. Numerical results can be achieved without manual drawing and rough estimation.

Index Terms— Medical Image Processing, Intra-Ocular Lens, Medical Software, Software Development, Glistenings Detection

I. INTRODUCTION

Following cataract or refractive lens surgery, the crystalline lens of the human eye is replaced by an artificial intraocular lens (IOL) typically inserted into the capsular bag [1]. When the IOL is in an aqueous environment, glistenings, which are fluid-filled microvacuoles, can be observed [2], [3], [4], [5], [6], [7]. Many studies report the formation of glistenings although the times of onset can be different [see 2 for a review]. The earliest reported onset of glistenings is one week postoperatively [2]. although, in some patients, glistenings were not found up to 6 months post implantation [2]. Irrespective of time of onset, the general trend is for the density of glistenings to increase with time [2], [5], [8]. There are many factors influencing the formation of glistenings, for example change in temperature, IOL material composition, IOL manufacturing technique, IOL packaging [2], [4], [5], [9], [10], [11].

Glistenings are important because they can affect vision by increasing forward light scatter [12], [13], [14]. The amount of light scatter is likely to be affected by the size, density and location of the glistening. To our best knowledge, no algorithm has been published for glistenings detection although a few studies suggest that other groups have looked at detection using image processing [15].

Exudates are lipids and leakage of proteins [16], [17]. Hard exudates are seen as bright yellow lesions with different sizes, shapes, and locations [16]. Blobs are defined as a brighter or darker region compared with the surrounding area or in the same color in the image or video [18], [19].

The techniques used for the detection of exudates and blobs can be adapted to use as glistenings detection.

In this paper, a collaboration between researchers from Thammasat University in Thailand, Kingston University and City University in London, we propose an effective intraocular lens glistenings quantification software. This novel software has a user friendly front-end and is designed to semi-automatically detect glistenings. Once detected, the software computes and displays important properties for the user. Its GUI is designed for the convenience of users who are typically clinicians or scientists with little image processing knowledge. The software is built based on Matlab. The paper is organized as follows: Section 2 briefly describes the procedure for glistenings detection; Section 3 presents a detail of software features; The conclusion and future work are showed in Section 4.

II. PROCEDURE FOR GLISTENINGS QUANTIFICATION

A. Overall Procedure

For the quantification of the glistenings on an IOL, the boundary of lens is detected. The radius is then calculated and the area of interest is divided into zones. Then glistenings are detected and the software calculated many properties such as area, density, glistenings distribution. We validate the glistenings detection result by comparing with the clinician's hand-drawn ground-truth image. The overall procedure is shown in Fig.1.

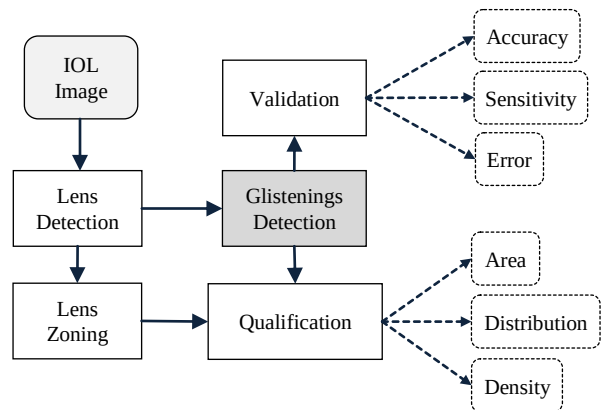


Fig. 1. The procedure of glistenings quantification.

B. Lens Detection and Zoning

Lens is detected from the image by finding the circumference of the lens. We assume that the radius of IOL Lens is 6 mm, we then divided the lens into 3 concentric zones; 3 mm, 4 mm, and 5 mm, representing the different

pupil sizes for respective light conditions. Glistenings are quantified within the different zones for further clinical analysis. Fig. 2 shows zoning system in this paper.

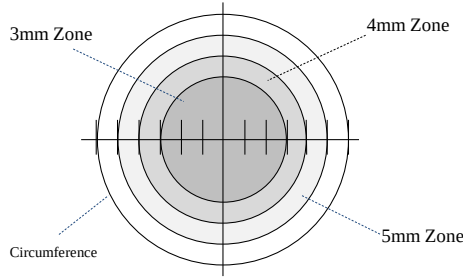


Fig. 2. Lens Zoning: 3mm, 4mm, and 5mm zones

C. Glistenings detection

Image processing techniques are used to detect the glistenings. Sobel operator is employed to detect the edge of glistenings. Sobel is a mask operation which is a first order differential edge detection. In our method we applied both x and y coordinates and combined the two results into one image. Due to Sobel mask have very high contrast line in the image. Dilation operation is used for connecting the lines. All gaps in the result of dilation will be filled. After all operation, we get the result of glistenings area together with some noise of uninterested area. To improve the efficiency, we use erosion operator to remove area which smaller or larger than our expecting target size.

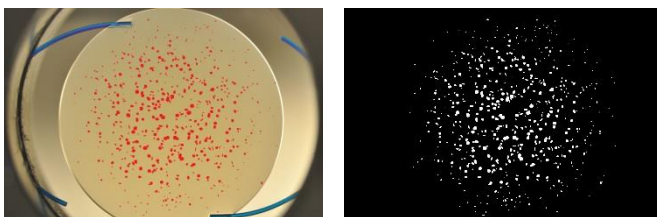
D. Glistenings Quantification

All detected glistenings will be used in the calculation of its properties, namely, areas, distributions and densities in all 4 regions; whole lens, in 3mm zone, 4mm zone, and 5mm zone.

An area of each microvacuole is a number of pixels detected as glistenings. The average area of each zone is used to compare with the sizes of glistenings. The distributions can show whether glistenings are located on the lens evenly or it can be inspected whether most of them are located on which zone. Then the density of glistenings of each zone is calculated by the summation areas of glistenings dividing by the area of the zone.

E. Result Validation

The accuracy, sensitivity and error are used to inspect the performance comparing the glistenings detection result with the ground truth. The glistenings in ground truth images are hand marked in red color by trained clinician as shown in Fig 3.



a) b)

Fig. 3. Example ground truth image. Left hand side:Red marked Glistenings Image and Right hand side:White marked Glistenings

III. SOFTWARE FEATURES

Because glistenings input image may have different formation, size, density and position, to create a front-end which adaptable to every type of glistenings, the proposed front-end is composed of many features. Its features include IOL image selection and display, lens detection, parameter configuration and glistenings detection, ground truth selection, layer selection, quantification result and validation details.

A. IOL Image Selection and display

User can select the IOL image by opening the image file. The IOL image can be 4 types: JPG, TIFF, PNG, and GIF.

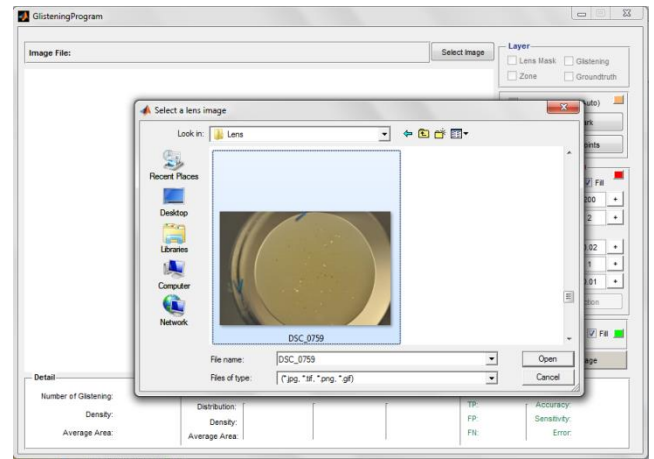
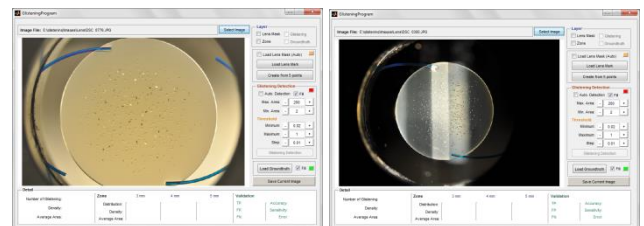


Fig. 4. IOL image saving window.

B. Lens Detection

Before glistenings detection process, we need to specify the region of lens. This front-end includes 2 ways to identify the boundary of the lens. First, user can load lens mask by selecting lens mask image file where white area is the region of interest of the lens. Fig. 6 shows the example of IOL image and its lens mask image. If the user doesn't have mask, user can create a mask semi-automatically by specifying 5 different locations on the lens' boundary. Lens mask area is then created by program and show on the screen. Fig. 7 shows the example of lens mask creation by clicking on the IOL image 5 times.



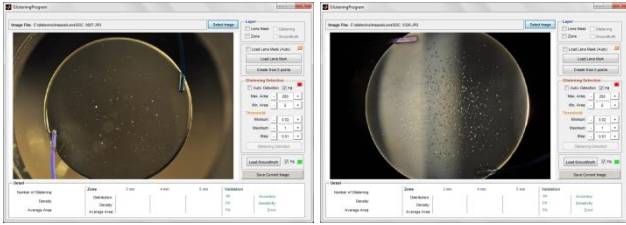


Fig. 5. IOL Image Showing Examples

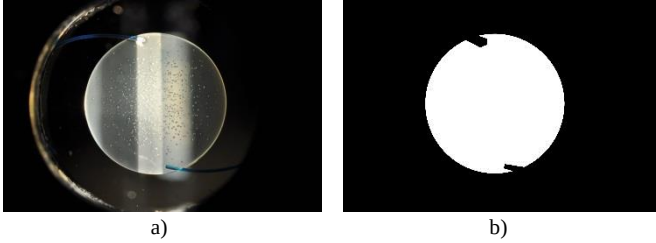


Fig. 6. IOL image and its lens mask.

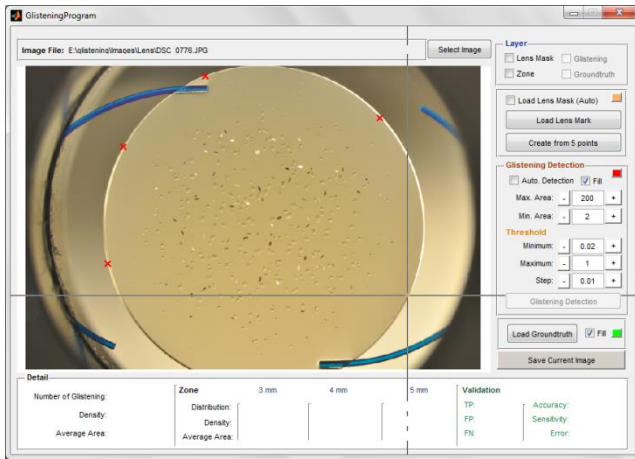


Fig. 7. 5 points clicking to create lens mask

C. Glistenings detection

In glistenings detection part, user can adjust many parameters for a variety of glistenings image input. There are 5 variables in this part consisting of Maximum area of glistenings (Max. area), Minimum area of glistenings (Min. area), Minimum Threshold, Maximum Threshold and step. User can choose the color of glistenings and choose to show only the boundary line or the glistenings area filled with color. Fig. 8 shows the example of glistenings area filled with color and Fig. 9 Shows example of glistenings boundary line and lens mask line.

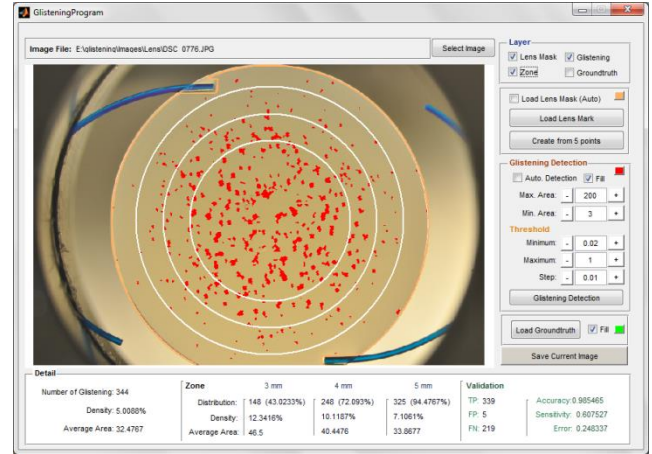


Fig. 8. Screen of program, shows filled-glistenings, lens mask and zone boundaries.

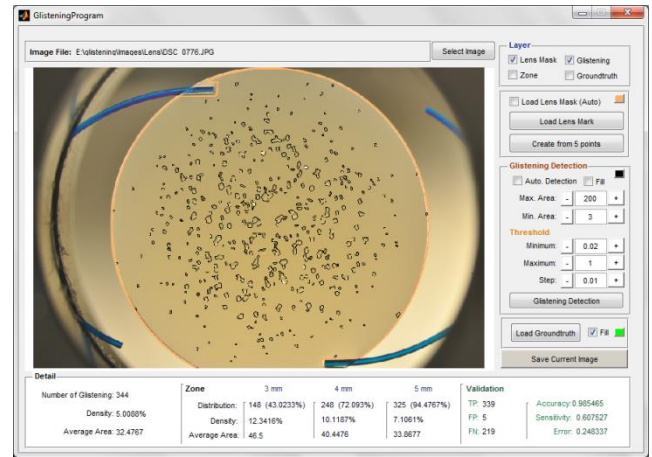


Fig. 9. Screen of program, shows the edges of glistenings and lens mask line

D. Ground truth Selection (for development phase)

During the program validation phase, user can load a ground truth image and compare it with the automatic glistenings detection result. Specificity and Sensitivity will be automatically calculated.

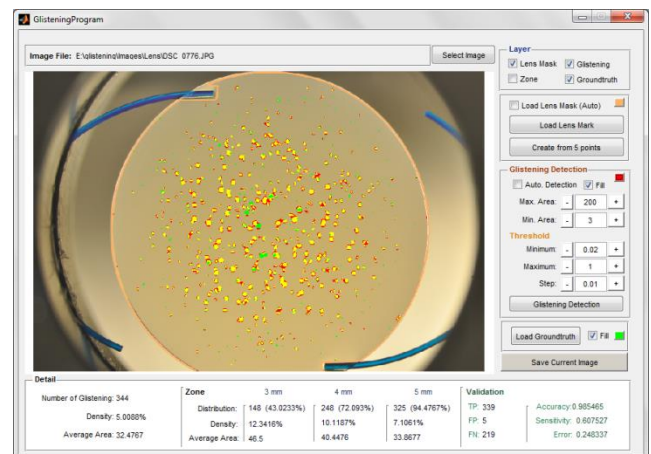


Fig. 10. Screen of program, shows the comparing of detected glistenings and the ground truth.

E. Layer Selection

User can select the layers to be shown on the IOL image. There are 4 layers; Lens Mask, Zone, Glistenings, and Ground truth. The example of the comparing of detected

glistenings, ground truth area and lens mask are shown in Fig. 10 and the filled-glistenings from ground truth and zone boundary are shown in Fig. 11.

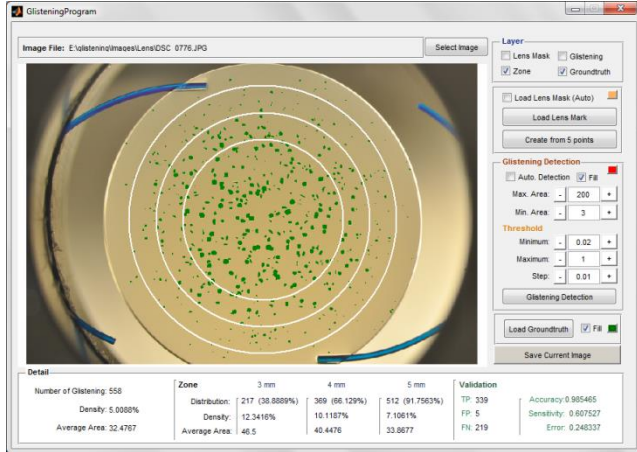


Fig. 11. Screen of program, shows the filled-glistenings from ground truth and zone boundary

F. Image Saving

Save Current Image button is also added to help the user save current processing image.

G. Quantification Result

Result of the glistenings detection is shown on the Quantification Detail. Overall result is shown on the left hand side of the screen for easy access. The results consist of the number of glistenings, density and average area. Next panel shows results from each zone of IOL lens. The results show the distribution, density and average area of each zone.

H. Validation Result

The accuracy and sensitivity are used to compute front-end performance. The accuracy is the result of the correct result divided by the total number of classifications and sensitivity is the result of the true positive and the condition negative. After user chose ground truth image, true positive (TP), false positive (FP), false negative (FN), accuracy, sensitivity and error would be shown on the right hand side of the detail section.

IV. DISCUSSION & FUTURE WORK

This paper proposed a software that is designed to detect glistenings and accurately compute important properties for the user. Glistenings detection results along with its properties are shown on the screen, comfortably help user to analyze glistenings in real time. Its GUI is simplified for the convenience of users, even the first time user can find it easy to use. The software is built based on Matlab. It has easy-to-use GUI and semi-automatic algorithm to detect and quantify the glistenings. It is suitable for users who want accurate and quick glistenings detection. Numerical results can be achieved without manual drawing and rough estimation.

There are still limitations on the currently proposed software that need to be developed. Size of IOL is considered as standard at 6mm while there are IOLs in

market with different diameters. In the case of glistenings overlapping, software is yet weak to distinguish.

For the future work, we will focus on the efficient algorithm for glistenings detection. We intend to develop a new technique which is more accurate and effective.

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