Detection, Categorization, and Assessment of Eye Cataracts Using Digital Image Processing

Md. Anayet U. Patwari  
Islamic University of Technology (IUT)  
Department of Mechanical & Chemical Engineering  
Board Bazaar, Gazipur-1704, Dhaka, Bangladesh  
Corresponding Author’s Email: aupatwari@hotmail.com

Muammer D. Arif  
Islamic University of Technology (IUT), Bangladesh

Md. N. A. Chowdhury  
Islamic University of Technology (IUT), Bangladesh

A. Arefin  
Islamic University of Technology (IUT), Bangladesh

Md. I. Imam  
Islamic University of Technology (IUT), Bangladesh

Abstract- Ocular Cataract are the leading cause of blindness. The diagnosis of cataracts is costly for poor people. The authors used a novel digital image processing technique in order to diagnose cataracts. For their study, the authors used digital images of 6 eyes (6 patients) with varying degrees of nuclear cataract, 4 eyes (4 patients) with varying cortical cataracts, and 3 normal eyes (3 healthy people). The pictures were converted to greyscale and then to binary formats for finding the relative variations in pixel intensities between healthy and cataractous eyes. The three normal eyes served as reference. Hence, the software was able to detect the presence of cataracts. Digital ‘masks’ were used for edge detection (boundary between healthy and cataractous portions of eyes) and subsequently classify the cataract into nuclear or cortical. Then the severity of each cataract was determined and its contour plotted. The technique was verified using prior physicians’ evaluations. Two test cases were used to perform clinical evaluations of the technique. The technique has 94.96% accuracy and 95.14% reliability.

Keywords- Cataracts, Clinical Trials, Contour 3-D Surface, Image Processing

I. INTRODUCTION

The lens has two main optical functions: (1) transparency and (2) refractive power [1]. The denaturing of cellular lens proteins leads to cataracts which scatter incident light [2]. As the cataract develops it becomes denser and involves greater part of the lens. The result is progressive clouding of the lens, loss of vision, and reduction of contrast sensitivity; especially to blue-violet shades [3]. Cataracts are classified, based on their location, into nuclear (NC), cortical (CC), or posterior subcapsular cataract (PSC); [4]. Aging, enzyme actions, heredity, congenital infections, hypertension, diabetes, renal failure, glaucoma and metabolic or ionic changes have been blamed [1]. External factors such as: heavy smoking and drinking, ultraviolet, microwave, or infrared radiations, corticosteroids, and trauma etc., can also cause cataracts [5].

Cataract detection is usually performed by an ophthalmologist through various eye tests. The final diagnosis is
therefore subjective, slow, and expensive. Various researchers have tried to address these issues. Fujikado et al. [6] used higher-order aberrations, and light scattering to estimate the visual deterioration of cataractous eyes. Abraham et al. [7] employed computer-aided (CAD) techniques to analyse diagnostic images of NC and CC for epidemiological research. They demonstrated that their technique had a mean bias similar to expert ophthalmologists but, unlike the experts, had zero variability. Acharya et al. [8] published a multinational research to objectively identify anterior segment eye abnormalities, including senile cataracts, using radial basis function (RBF) classifier and fuzzy K-means algorithms.

Reducing the backlog of cataract-blind requires training ophthalmic personnels, reinforcing health care infrastructures, economizing costs, and making surgical supplies available [9]; these are lacking in developing nations. A cheap, reliable, and automated cataract detection and evaluation system will greatly reduce treatment costs, increase health care levels, and improve the quality of life. Cataracts, after all, are one of the curable types of blindness.

The authors referred to the previous works for guidance and modeled the logical sequence of their analysis on the previous work of Arif et al. [10]. MATLAB 2008 image processing toolbox [11] was used to develop the simple and reliable technique to detect cataract, classify its type (NC or CC), measure its severity, and finally generate 2 and 3-D coloured contour images for visualization and surgical aid. The software also used expert knowledge to suggest subsequent visual tests for more efficient diagnosis.

II. EYE AND CATARACT STRUCTURE

The function of the lens is to focus incident light in order to form clear real images on the retina. The cataractous lens is cloudy and often swollen. Incoming light rays are scattered and fail to form crisp images on the retina. The condition can deteriorate from partial to complete blindness as the cataract progresses. Fig. 1 represents the phenomenon of light scattering by cataract [12].

Cataracts are mostly of two types: Nuclear and Cortical Cataracts, with the majority being NC. PSC also exists but is less common. Thus, the authors of this research focused their efforts on designing a technique to detect NC or CC.

Nuclear and Cortical Cataracts

Nuclear cataracts result due to the gradual opacification and yellowing of the intraocular lens’ nucleus. The usual NC structure is circular when the affected lens is photographed.

Cortical cataracts develop in the cortical regions surrounding the nucleus of the eye lens. They usually have a characteristic elongated shape, unlike NC, and appear as spokes around the central nuclear region of the lens. Fig. 2 is a schematic representation of NC and CC [13].

III. DETAILS OF THE METHOD

A. Sources of Clinical Data

Digital images of healthy and cataractous (NC and CC) eyes were obtained from [7] and [14]. These were used to
calibrate the system (generate the ‘digital masks’ and specify the grey level intensity and circularity thresholds) for detection, classification, evaluation, and contour generation of the cataracts. The digital images of two cataractous eyes, an elderly woman’s with senile cortical cataract and a child’s with congenital nuclear cataract, were used for clinical evaluation of the system.

**B. Method Sequence and Explanations**

The lens image is first extracted from the patient’s photo. The RGB image is then converted to resized greyscale for standardizing the comparison and reducing the calculation load by a third. The presence of the cataract is then detected by comparison with the mean grey intensity of healthy eyes obtained from 3 normal eyes. The image is further converted to black and white, for edge detection and circularity measurement. Image morphological feature (total pixel number < 30) is used for noise reduction. The filtered image is subsequently converted to binary format and its circularity compared to the circularity threshold of the mask (ideal NC or CC binary shape). As previously mentioned NCs are usually circular whereas, CCs commonly resemble elongated ellipses [13]. From the patient data obtained, [7] and [14], it was found that NC and CC circularity varied from 0.96 to 0.84 and 0.65 to 0.07, respectively. Thus, a circularity measure threshold of 0.80 was used to differentiate between NC and CC. Cataract severity was then calculated from pixel data and the relevant contour graphs rendered.

A final report was output by the software listing further eye exams that the patient needs to take depending upon the type of cataract detected [13]. Fig. 3 illustrates the steps used.

![Flow chart of the method](image-url)

**Fig. 3** Flow chart of the method
IV. RESULTS AND DISCUSSIONS

The automated cataract detection technique displayed accuracy and repeatability, for NC and CC detection, of 94.96% and 95.14% respectively. The repeatability of the software was obtained by comparing its evaluations of 3 separate images of each individual eye. These results of the software’s performance are consistent with the findings of [7].

It was observed that the software consistently under-evaluated the severity when the eye had less than 50% opacity, and over-evaluated the severity when opacity was more than 50%, for both NC and CC. It was also seen that the software was more accurate and consistent in evaluating NC than CC. This later phenomenon was due to the fact that the images used were of moderate resolution and that the algorithm developed is extremely sensitive to variations in mean grey scale intensities of pixels and their circularity measures. Therefore, measurement of the severity and subsequently classification of CCs is more difficult than NC as CCs consist of spokes of opacities.

After the severity calculations the software used generated contour graphs and recommendations for further relevant eye exams to be undertaken by the patient. The results are listed in Table I.

<table>
<thead>
<tr>
<th>No.</th>
<th>Evaluator</th>
<th>Cataract Type</th>
<th>Severity %</th>
<th>Error %</th>
<th>Repeatability</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal</td>
<td>0</td>
<td>0.00</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Normal</td>
<td>0</td>
<td>0.00</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Normal</td>
<td>0</td>
<td>0.00</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>NC</td>
<td>28.00</td>
<td>-6.67</td>
<td>96.50</td>
<td>Calibration</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>NC</td>
<td>37.00</td>
<td>-7.50</td>
<td>97.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>NC</td>
<td>48.00</td>
<td>-4.00</td>
<td>96.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>NC</td>
<td>63.00</td>
<td>5.00</td>
<td>95.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>NC</td>
<td>84.00</td>
<td>5.00</td>
<td>96.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>NC</td>
<td>100.00</td>
<td>0.00</td>
<td>95.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>NC</td>
<td>95.00</td>
<td>5.56</td>
<td>97.00</td>
<td>Calibration</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>CC</td>
<td>23.50</td>
<td>-6.00</td>
<td>95.00</td>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>CC</td>
<td>47.00</td>
<td>-6.00</td>
<td>94.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>CC</td>
<td>73.00</td>
<td>4.29</td>
<td>96.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>CC</td>
<td>100.00</td>
<td>0.00</td>
<td>93.00</td>
<td>Calibration</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>CC</td>
<td>36.00</td>
<td>-10.00</td>
<td>92.00</td>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>NC</td>
<td>4.82</td>
<td>96.29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>5.26</td>
<td>94.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>5.04</td>
<td>95.14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
V. CONCLUSIONS

The good repeatability of the automated system is very useful since even expert ophthalmologists and eye specialists show repeatability problems which may lead to disagreement among physicians. Also, the authors are hopeful that the 2 and 3-D contours generated by the software will enable the ophthalmologist, eye care provider, and the patient to visualize the cataract(s) in entirety.

The shortcomings of the software are that the algorithm is sensitive to grey level variations which leads to the error measured. The error can be reduced by development of a more complex algorithm, better background noise reduction, adjustment for uniform illumination, and application of advanced cameras.

At the present the application of this software requires that the user is well acquainted with MATLAB. However, the authors are currently designing a Graphical User Interface (GUI) to make the diagnostic software more user friendly.

This research focused on only NC and CC. Nevertheless, Posterior subcapsular and mixed morphology (combined NC & CC) cataracts also exist, though they are rarer [1]. The authors believe that with further modification they will be able to calibrate the software to identify and evaluate these two types.

The high accuracy and reliability of the technique indicates, in the authors’ opinion, that it is ready for trials with large data sets under real clinical conditions.

REFERENCES


