Abstract—This article describes the development of a smartphone application with the goal to detect and analyze the keratoconus using images captured by a keratometer based on LED ring. This application detects LED reflection in the patient eye and calculates the curvature around the center of the cornea using an interpolation algorithm. The reliability was verified using high degree of aberration images and ellipses images with known parameters to test the software. Comparing real parameters of the simulated images with the obtained by the software the absolute errors are very small. For images of a data bank the software detects all LEDs images and calculates the ellipse axes and inclination angle. For very high degree of aberration the detection is problematic.

Keywords: Smartphone, keratometer, android, mobile, healthcare

1. Introduction

Researchers and professionals that work with medical ophthalmic instruments are improving methods and measurement techniques in optical systems, data analysis, diseases diagnostics and improving the surgery procedures on patients [1]. New equipment for improving health care does not always need sophisticated and expensive computer systems, but inexpensive ones that most of us have in our pocket: the smartphones [4]. The smartphones have become integrated into our lives. The devices have evolved incredibly during the last years, an evolution that can contribute to develop applications in the ophthalmology medical field [2]. Smartphones have many sensors embedded on such as cameras, GPS, gyroscope, accelerometer and internet access, allowing the development of sophisticated applications as the processor are getting faster. However, developing real time application is still a challenge. Researchers and professionals are developing library’s with fast algorithm to improve the processing time [3], an example is the image processing that are very small. For images of a data bank the software detects all LEDs images and calculates the ellipse axes and inclination angle. For very high degree of aberration the detection is problematic.

2. Method and Goal

The project goal is to develop a smartphone application to detect keratoconus in patients. The software is implemented in Android Operational System using the JAVA platform, with OpenCV library to manipulate images data. The proposal is to develop an application to be used on remote area to collect information and transmit it to a doctor or specialist to diagnose the problem. The program identifies and locate the keratometer LED’s projection, performs the Lagrange interpolation, and send the processed data to be analyzed.

2.1 Lagrange Interpolation

Lagrange interpolation is in most cases the method of choice for dealing with polynomial [5]. Given a set of \( n + 1 \) distinct interpolation points \( k_j \), \( j = 0, ..., n \), together with corresponding numbers \( f_j \). Assuming that the nodes are real, let \( \prod_n \) denote the vector space of all polynomials of degree at most \( n \). The problem addressed is that of finding the polynomial \( p \in \prod_n \) that interpolates \( f \) at the points \( x_j \) [5]. The formula finds a continuously solution with the data captured in the image. The Lagrange form [6] are:

\[
p(x) = \sum_{j=0}^{n} f_j l_j, \quad l_j = \frac{\prod_{k=0, k \neq j}^{n} (x - x_k)}{\prod_{k=0, k \neq j}^{n} (x_j - x_k)} \quad (1)
\]

This interpolation algorithm is used to calculate the major axis, minor axis, angle and dioptre of the circle image projected onto the patient eye.

2.2 Image Processing

After capturing the image projected onto the patient eye using the LEDs keratometer [Fig. 1], an 7x7 pixels mask is used to find the area where the sum of intensity have higher value, this area is the more probable place of a LED projection. This area is used as a new mask, and have twice the size as the preview mask. The new mask is used to find the other LEDs projection. A convolution with the new mask is made, to calculate the difference between the new mask and each region in the image. The absolute value of this difference and the position of each area are stored in a list sorted in descending order of intensity. Then, the last \( N \) elements on the list are selected after verifying if these elements are not too close to each other in order to avoid overlapping. The next step is to apply the Lagrange interpolation using the points found to calculate the segment between two points in polar coordinates.
Fig. 1: Image with projected LEDs.

Fig. 2: Detection of 36 LEDs and Lagrange Interpolation.

Lagrange interpolation used two posterior points and two anterior to calculate the segment. After finding the segment the program calculates the major axis, minor axis and the angle.

The program is tested using images with all the parameter known, an absolute error is calculated comparing the parameters obtained by the program and the real ellipse parameters, furthermore a set of irregular image is used to analyze the reliability. The data compared are the ellipse angle, major axis and minor axis, the images with known parameters have 480 X 360 resolution, the major axis length is between 100 and 150 pixels, the minor axis has length superior than 100 and lesser or equal than the major axis and the angle is between 0 and 170.

3. Result

The parameters obtained by the software developed were compared with 54 images with known parameters. The major axis and minor axis error was below 4 pixels in both cases. Analyzing the angle data, it was observed that when the minor axis is closer to the major axis, higher is the angle error calculation. Images with higher degree of aberration also results in difficulties to detection of the LEDs projections. This leads to mismatch’s in the LEDs projection detection and Lagrange interpolation.

Images with higher degree of aberration the detection is problematic, the program developed does not find the LEDs projection correctly, because the images has too much noise. Since the LEDs detection is problematic the interpolation is incorrectly.

4. Conclusions

The project is still in development, but the results found in the tests were satisfactory, the algorithm locates the LEDs reflected and the Lagrange interpolation implemented is precise enough to avoid significant errors in case of missing LEDs. However, images with high cases of eye aberration, the detection still have some problem to locate and calculate the segment between two points, this aberration can cause overlapping LEDs projection or the image has too much noise.

Points to be worked in the future are, implement an algorithm to find an ellipse with the points calculated with the Lagrange interpolation, reduce the processing time, improve the algorithm, and to create a database in cloud to store the information captured in the field. This database should store basic information about the patient as, eye image and the parameters major and minor axes, dioptre, inclination angle, them allow doctors to access the data and make a diagnosis. Other improvements for this work are to use the keratometer ring with continuous light and to develop a corneal topographer for the equipment to map the curvature in a large area of the cornea.

References