Corneal topography reinterpretation through separate analysis of the projected rings

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Abstract

We present a new algorithm to process captured images of reflected Placido rings. Up to our knowledge, conventional topographers transform from Cartesian to polar coordinates and vice-versa, thus extrapolating corneal data and introducing noise and image artefacts. Moreover, captured data are processed by the device according to proprietary algorithms and offering a final map of corneal curvature. Corneal topography images consists of concentric rings of approximately elliptical shape. Our proposal consists of considering the information that provides each separate ring. A snake-annealing-like method permits identifying the ring even with discontinuities due to eye-lashes and reflections. By analysing the geometrical parameters of rings (centre, semi-axis and orientation), one can obtain information about small morphological micro-fluctuations and local astigmatisms. These parameters can be obtained with sub-pixel accuracy so the method results of high precision. The method can be easily adapted to work on any topographer, so that it can provide additional information about the cornea at no additional cost.

Method

The technique consists of a previous experimental arrangement¹ and an innovative algorithm. The algorithm is composed of an image processing phase, which includes the rings extraction process and the Elliptical Scanning Algorithm, and a curvature radii computation method. The fitting of an ellipse² which minimalizes the sum of the squared algebraic errors to each scanned ring, offers parameters such as ellipse axis, orientation and centre. These parameters are used to describe the morphology of the surface in annular areas and, by applying the analysis to a frame sequence, allow getting further information about dynamic changes of corneal surface.

• Rings extraction. Frame binarization and centring

Figure 1: a) Captured and b) processed image

The first step in the processing consists of adequate centring of the initial frames (Fig 1a) which is performed from centroid coordinates. Next, the frame is processed through mathematical morphology and binarized to facilitate the rings extraciton (Fig 1b).

• Rings labelling. Elliptical Scanning Algorithm (ESA)

The ESA is an effective method to individually detect and label the projected rings. It consecutively defines an elliptical annulus of one pixel wide which grows pixel by pixel and sweeps the image, from centre to periphery, until it detects and labels each ring. A one-pixel wide growing circular annulus, centred at zero, detects the inner ring.

Figure 2: Video of detected rings

• Radial distance to curvature radius conversion

The measured radial distances of the data in the labelled rings must be related to the correspondent curvature radii³. We propose obtaining a calibration surface.

Figure 3: Calibration surface

Once a ring is detected, it is used as seed to continue the scanning up to the next one. Pixels forming the ring are least square fitted to an ellipse, and parameters (centre coordinates, size of the axes and tilt) are used to implement the following one pixel wide elliptical annulus, which is used to scan the image and detect next ring. In figure 2, we present a case where we correctly detect up to 19 rings that corresponds approximately to the whole iris.

We have plotted the reflected rings' radii, R , (radial distances), rings' labels, I , and curvature radii, C (figure 3). We find that, besides the linear dependence between R and C , there also is a linear dependence between the slopes and the rings' labels I . We show the interpolating surfaces that represent the correspondence expressed as

$$R=(aI+b)C$$

Once we get the calibration equation, we can find the value of $C(x,y)$ at each pixel located in a frame at a distance $R(x,y)$ from centre, and being part of a reflected ring labelled with I .

Results

This work, like others^{1,3-5}, improves videokeratography algorithms by using open methods. The ESA allows an analysis of annular regions of the surface, fact that reduces the unequal density of samples in different sectors of the surface and improves the fitting. The new method increases data (figure 4) in one order of magnitude and reaches a wider corneal area. It is able to detect and correctly classify rings' fragments broken by the eyelashes. The method together with the adapted measuring device allows adapting a video camera to evaluate corneal morphology in time. The breathing frequency appears in figure 5a) where we plot relative variation in time of the mean curvature radius and 5b) its Fourier Transform.

Figure 4: Obtained curvature radii

Figure 5: a) Relative variation in time of the mean curvature radius and b) its Fourier Transform

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