AUTOMATIC DETECTION OF FEATURES IN ULTRASOUND IMAGES OF THE EYE

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Outline

- Introduction
  - Problem definition
  - Parameters of interest

- The algorithm

- Results

- Concluding Remarks
Introduction

- Developed an automated technique to analyze ultrasound images of the eye & measure Glaucoma angle

- Proposed technique addresses the following challenges with Ultrasound images:
  - Denoising
  - Poor resolution
  - Poor contrast
  - Weak edge (boundary) delineation
  - Identification and feature extraction
Problem definition

- Glaucoma involves increased fluid pressure inside the eye, which damages the optic nerve and causes partial vision loss and can progress to blindness.

- Early detection of Glaucoma could prevent total loss of vision:
  - Measure of IOP
  - Measure of open-angle
Parameters of interest

Feature A: Scleral Spur
Feature B: Apex point

Speckle noise
Features of interest

- Sclera
- Trabecular meshwork
- Apex point
- Scleral spur
- Iris
- 500 um location
- Anterior Chamber
Ultrasound images of the eye

Open (normal)  
Closed (diseased)

Intra-ocular pressure
THE ALGORITHM
Step 1

--- Coarse enhancement
--- Anterior chamber segmentation
Non-Linear Edge & Contrast Enhancement

Apex point 500 um location
Scleral spur

Original Coarsely Enhanced

IMTC 2005, Ottawa, Canada, 17th-19th May 2005
Template Correlation

- Correlation is used to locate the anterior chamber

- Template regions:

- Enhanced image is correlated with each template and the average correlation point is computed
Anterior Chamber Classification

- Each closed region is analyzed independently

- Classification is based on the geometrical properties:
  - object area
  - Centroid
  - major-axis
  - minor-axis length

**using an elliptical model**
cont’d...

- The following parameters are computed for segmentation of the closed regions:
  
  - **Center**: Defined as the center coordinate of a region
  
  - **Distance center-correlation point**: Must be minimized
  
  - **Area**: Must be > 50 pixels, otherwise, the region is considered to be speckle noise
Anterior Chamber segmented
--- Fine enhancement
--- Sclera segmentation
Histogram magnification

- A histogram magnification: enhance texture of sclera
- Threshold values: 15% and 85% of the total number of pixels
Region Subtraction

- Removes all large regions and keeps only fine details

Targeted region

IMTC 2005, Ottawa, Canada, 17th-19th May 2005
Sclera region classification and segmentation

- The following parameters are computed:
  (a) Right-most pixel of each closed region
  (b) Distance from the apex point to the right-most pixel is computed: **Must be minimized**
Step 3

-- Extra fine enhancement
-- Sclera region re-segmentation

3.1 Edge & Contrast enhancement ([9 9] Gaussian PSF, N=5)

3.2 Image Binarization

3.3 Re-segmentation of sclera

3.4 Contour map

3.5 4th order Butterworth LPF

3.6 Find Scleral spur point

3.7 Calculation of opening angle and AOD 500

Scleral spur detector
Sclera Contour Mapping

- 1-D signal plot of the contour
- Smoothing: Remove outliers and abrupt variations in the outline
Scleral Spur Detection

- The scleral spur is detected based on the following steps:
  1. A gradient operator is applied on the smoothed contour
  2. All minima coordinates & points along descendent edge prior are computed
  3. If no minima are detected, all points with zero gradient are located and defined as saddle edges
cont’d...

- Identification/detection of the scleral spur:

  - **One local minimum:** The scleral spur coordinate

  - **Multiple minima:** Calculate the magnitude $\Delta_{\text{edge}}$ of each edge prior to a minimum. The largest $\Delta_{\text{edge}}$ is chosen to compute the scleral spur coordinate

  - **No minima:** Select the saddle edge located most to the right of the 1-D outline
Determination of Measured Parameters

- Clinical parameters:
  
  (1) Open-angle exists if the 500 um point is located to the right of the Apex point

  (2) AOD 500: Through orthogonal projection from the trabecular meshwork to the iris
Outcomes of Algorithm

Scleral Spur Pixel offset error

(1) **Failure:** Can not segment regions

(2) **Success:** Clinical parameters are computed and differ from those measured by the technologist to within 97.5 um

(3) **Potential Fault/Error:** The offset error is greater than 97.5 um in either direction

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Failure / Success rate

- On a sample of 80 images:
  - Features were correctly identified in 97% of images (outcome 2)
  - 3% of images presented inaccurate estimates (outcome 3) of the clinical parameters, with 351 um offset error on average
Concluding Remarks

- We proposed an algorithm to automatically identify clinical features in ultrasound images of the eye.

- The algorithm computes the AOD 500 and the open-angle parameters.

- The algorithm predictions are very similar to the trained technologist’s observation.

- Success rate is approximately 97%.