AUTOMATIC DETECTION OF FEATURES IN ULTRASOUND IMAGES OF THE EYE

R. Youmaran, P. Dicorato, T. Hall, A. Adler

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

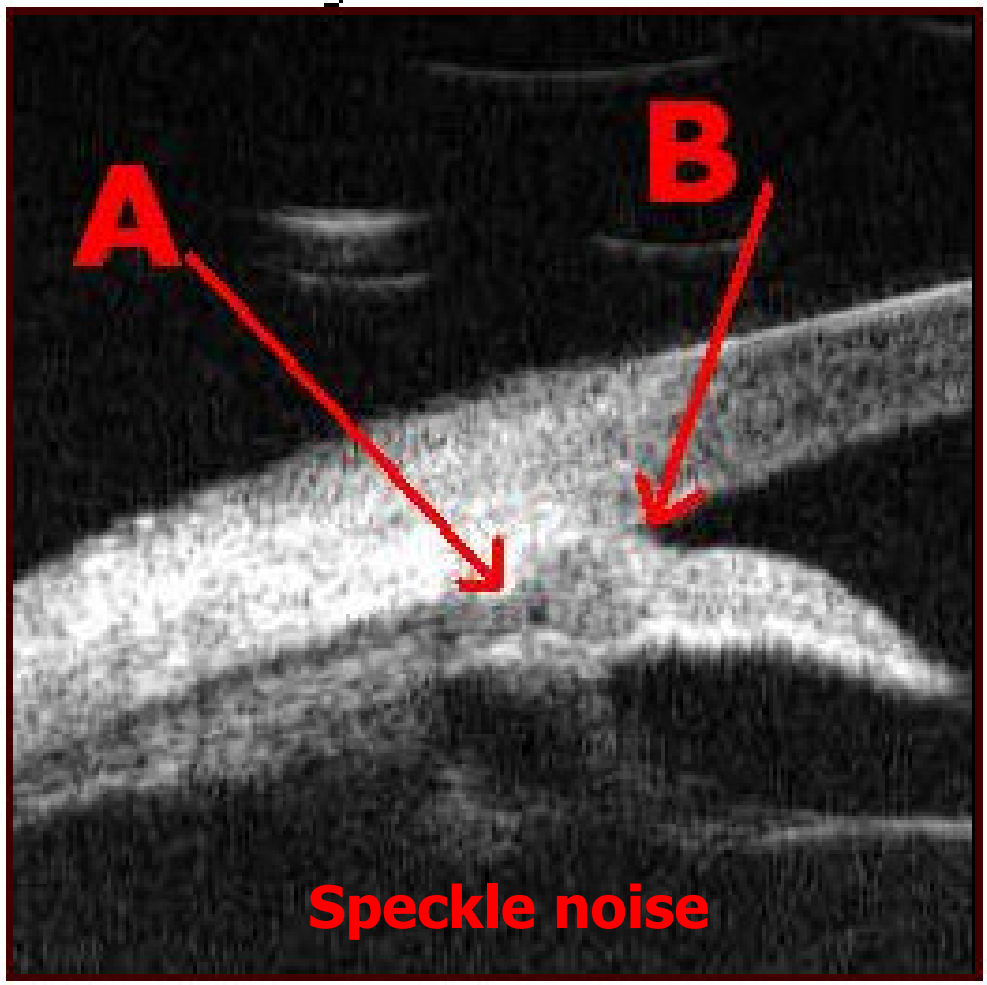
- Proposed technique addresses the following challenges with Ultrasound images:
  - Denoising
  - Poor resolution
  - Poor contrast
  - Weak edge (boundary) delineation
  - Identification and feature extraction

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

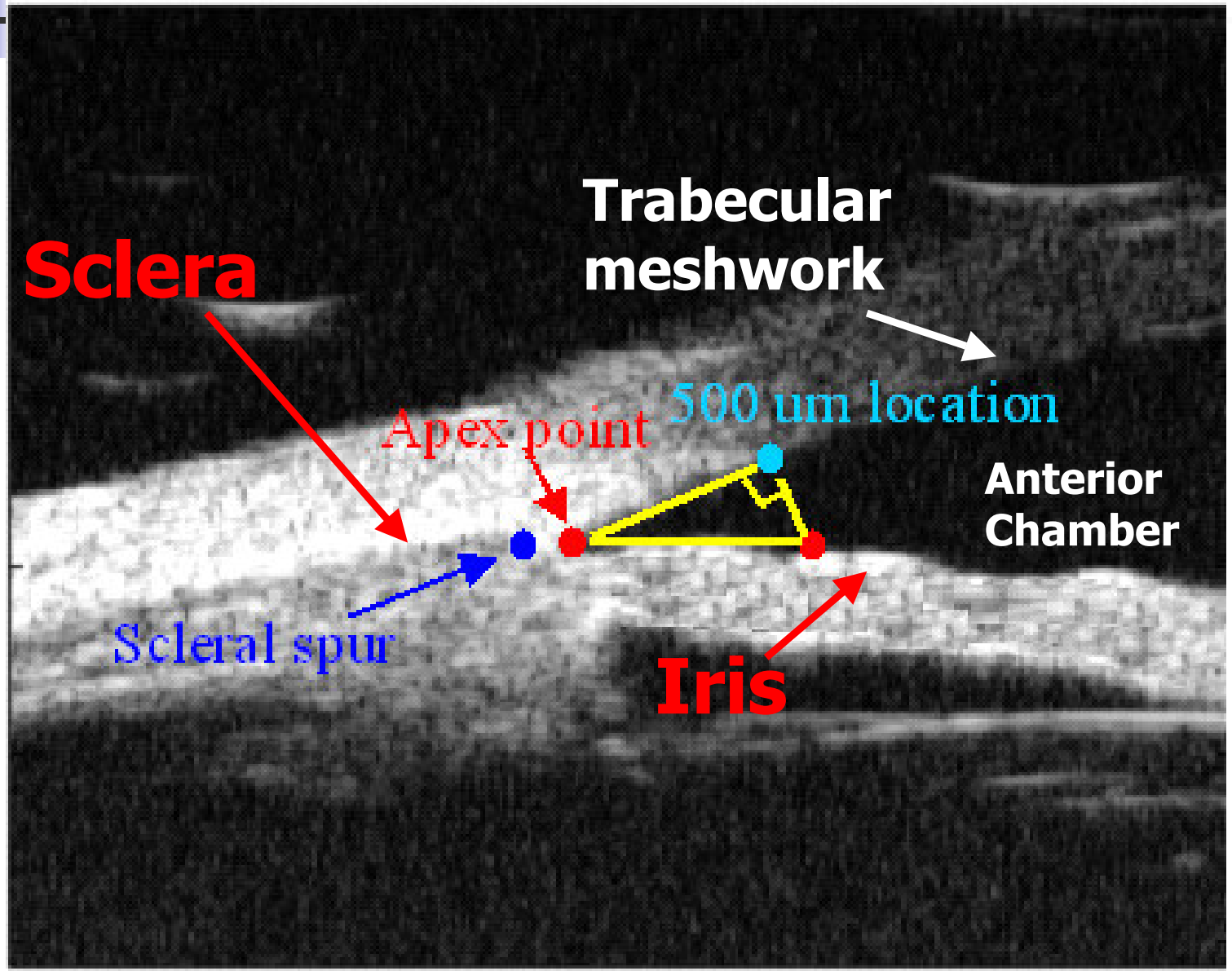
- Early detection of Glaucoma could prevent total loss of vision
  - Measure of IOP
  - Measure of open-angle

Parameters of interest



Feature A: Scleral Spur
Feature B: Apex point

Features of interest

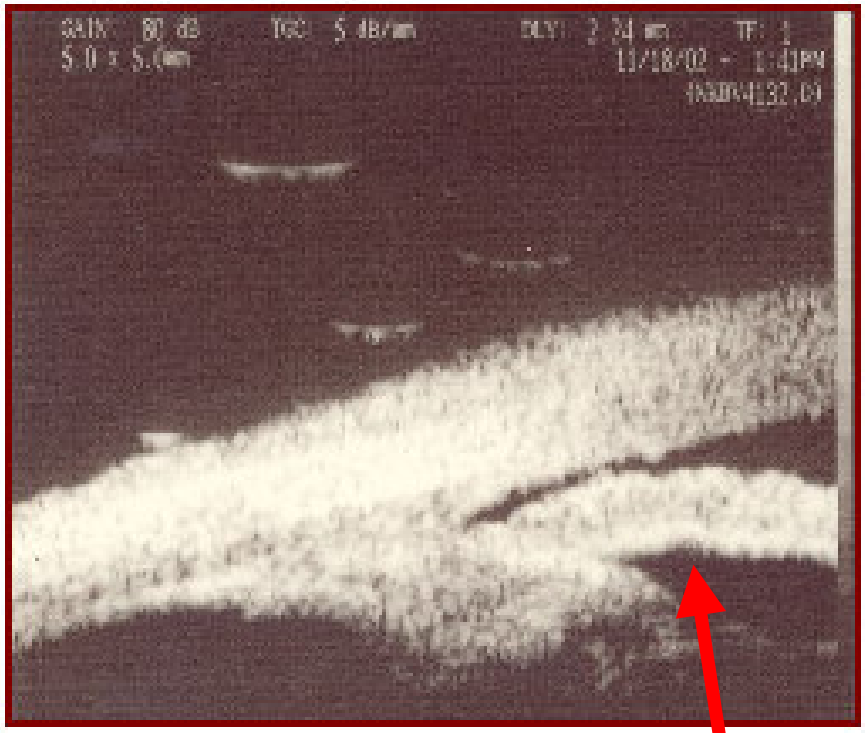


uOttawa
L'Université canadienne
Canada's university

Ultrasound images of the eye

Open (normal)

Closed (diseased)

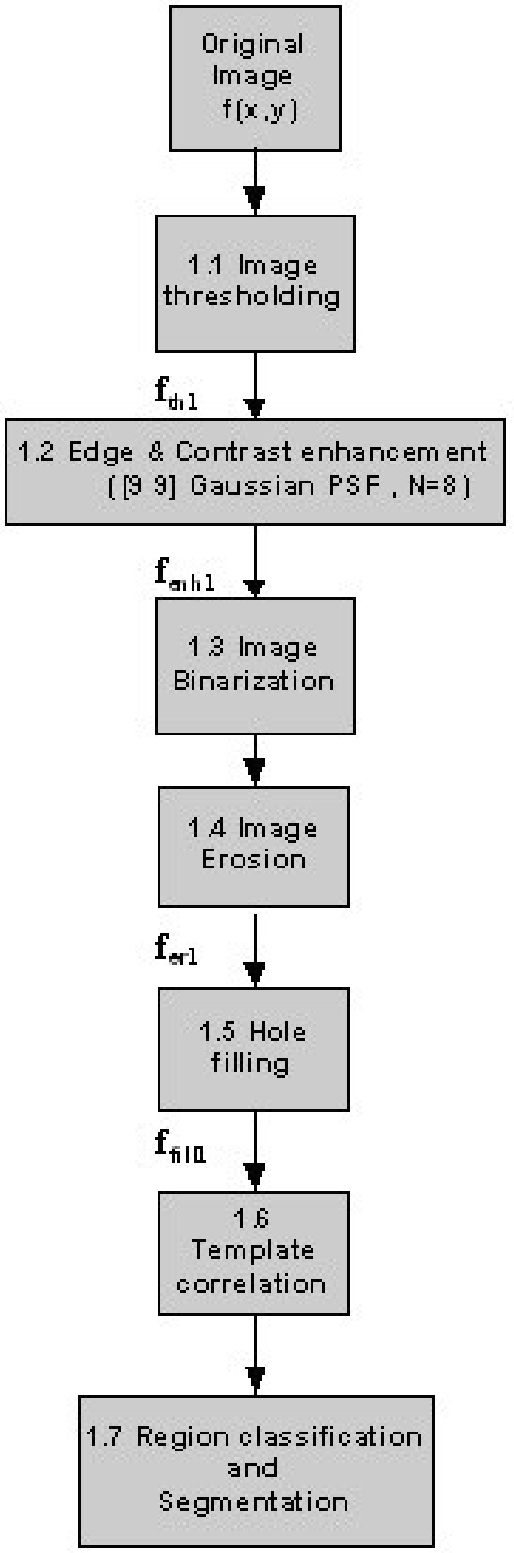


Intra-ocular pressure

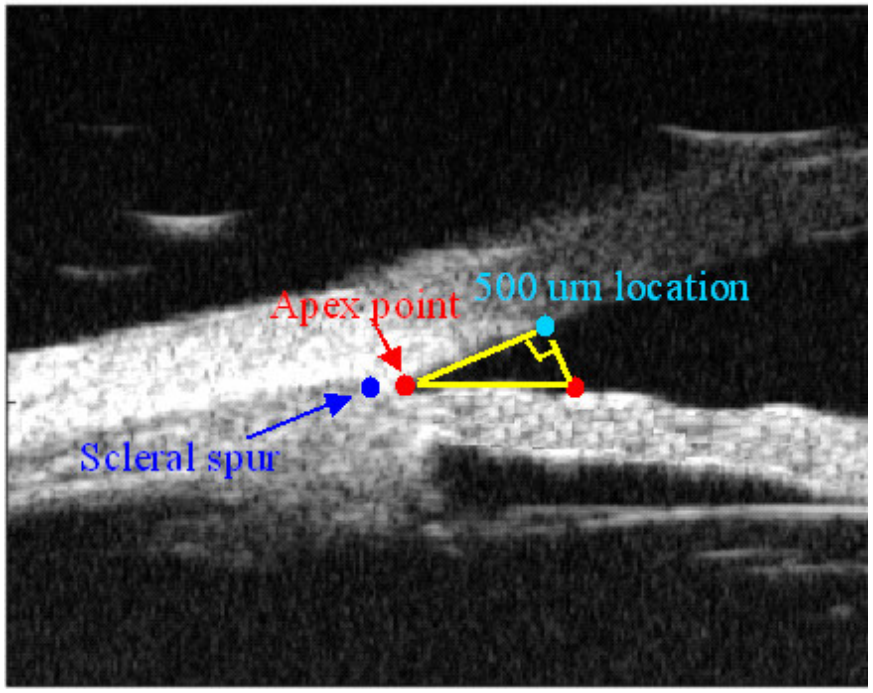
THE ALGORITHM

Step 1

--- Coarse enhancement
--- Anterior chamber segmentation



Non-Linear Edge & Contrast Enhancement



Original

Coarsely Enhanced

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

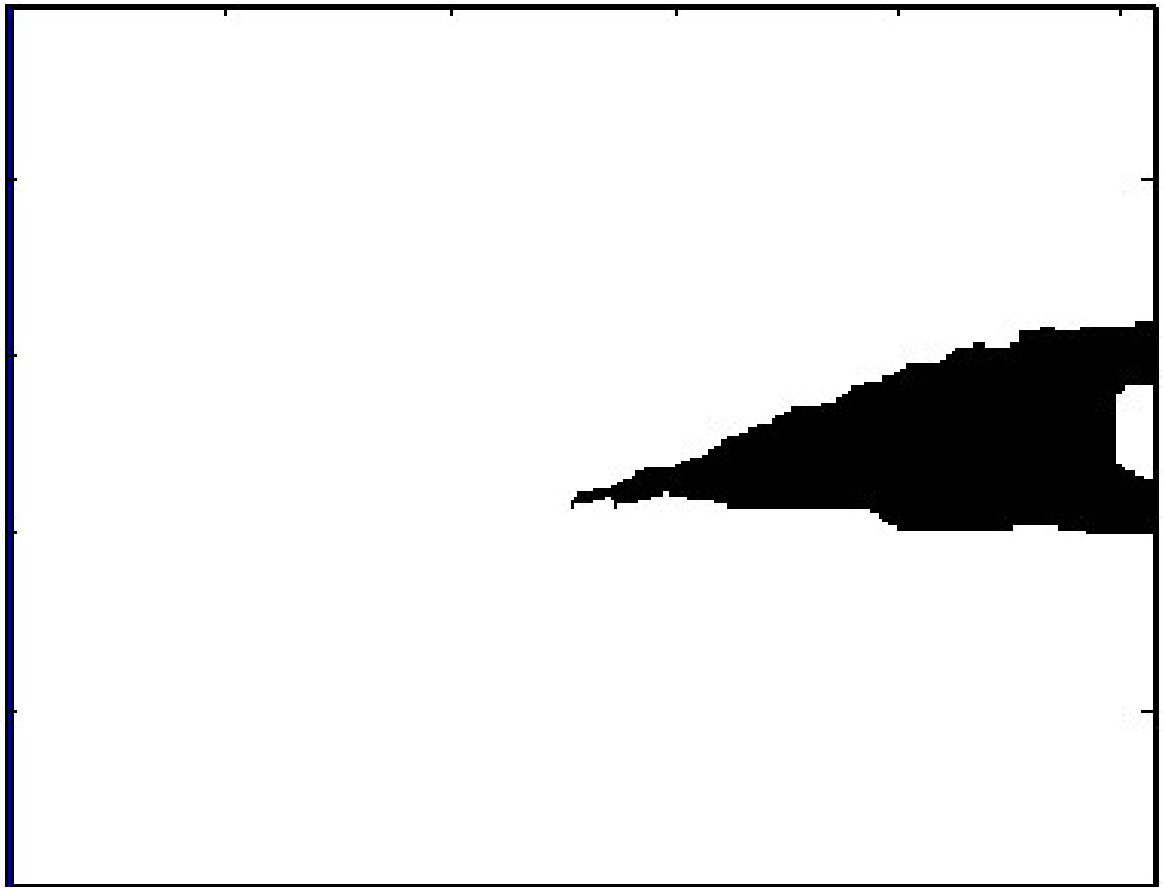
- Each closed region is analyzed independently
- Classification is based on the geometrical properties:
  - object area
  - Centroid
  - major-axis
  - minor-axis length

using an elliptical model

cont'd…

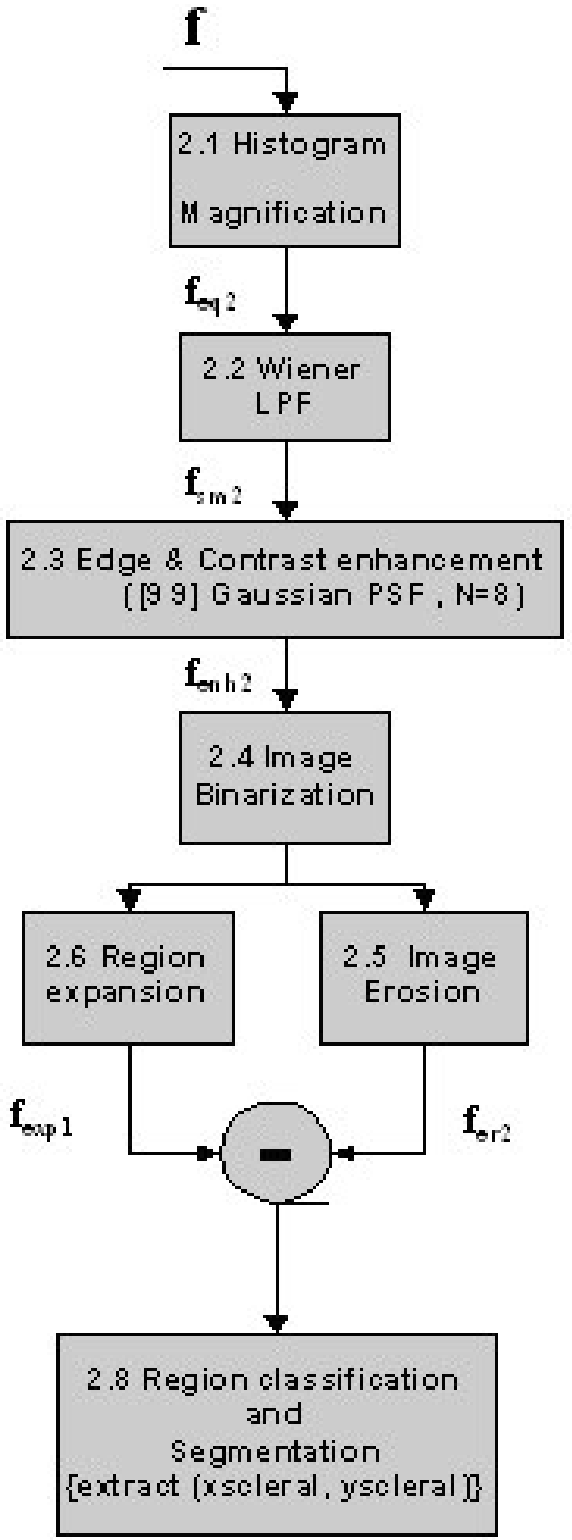
- The following parameters are computed for segmentation of the closed regions:
  - *Center*: Defined as the center coordinate of a region
  - *Distance center-correlation point:* **Must be minimized**
  - *Area:* Must be > 50 pixels, otherwise, the region is considered to be speckle noise

Anterior Chamber segmented



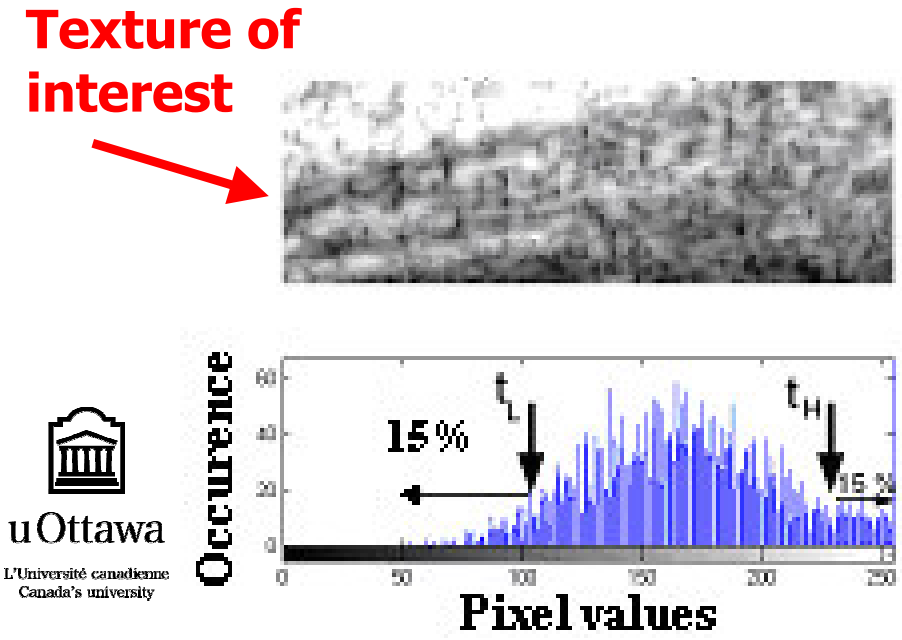
Step 2

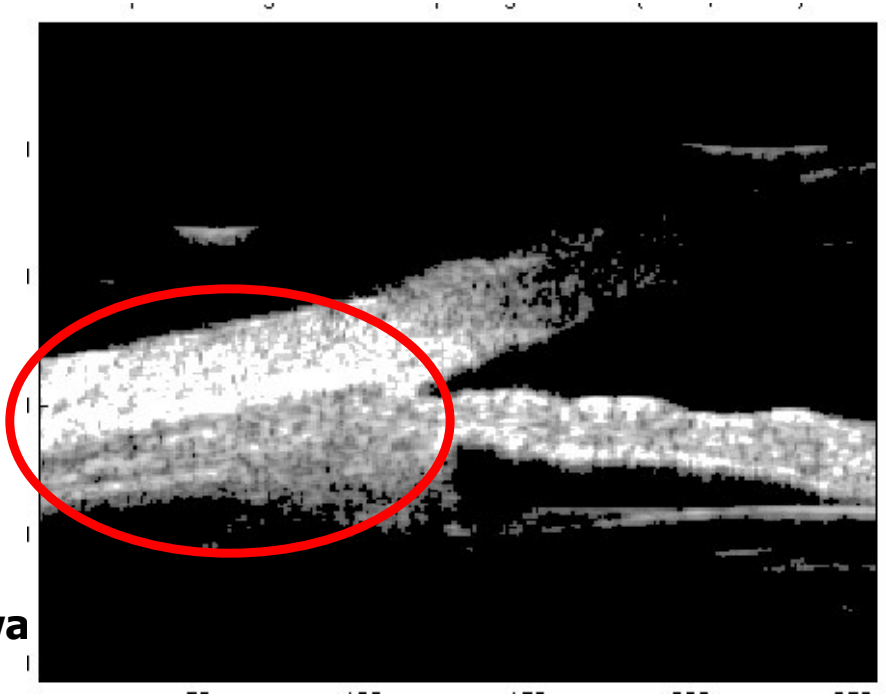
--- Fine enhancement
--- Sclera segmentation



Histogram magnification

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

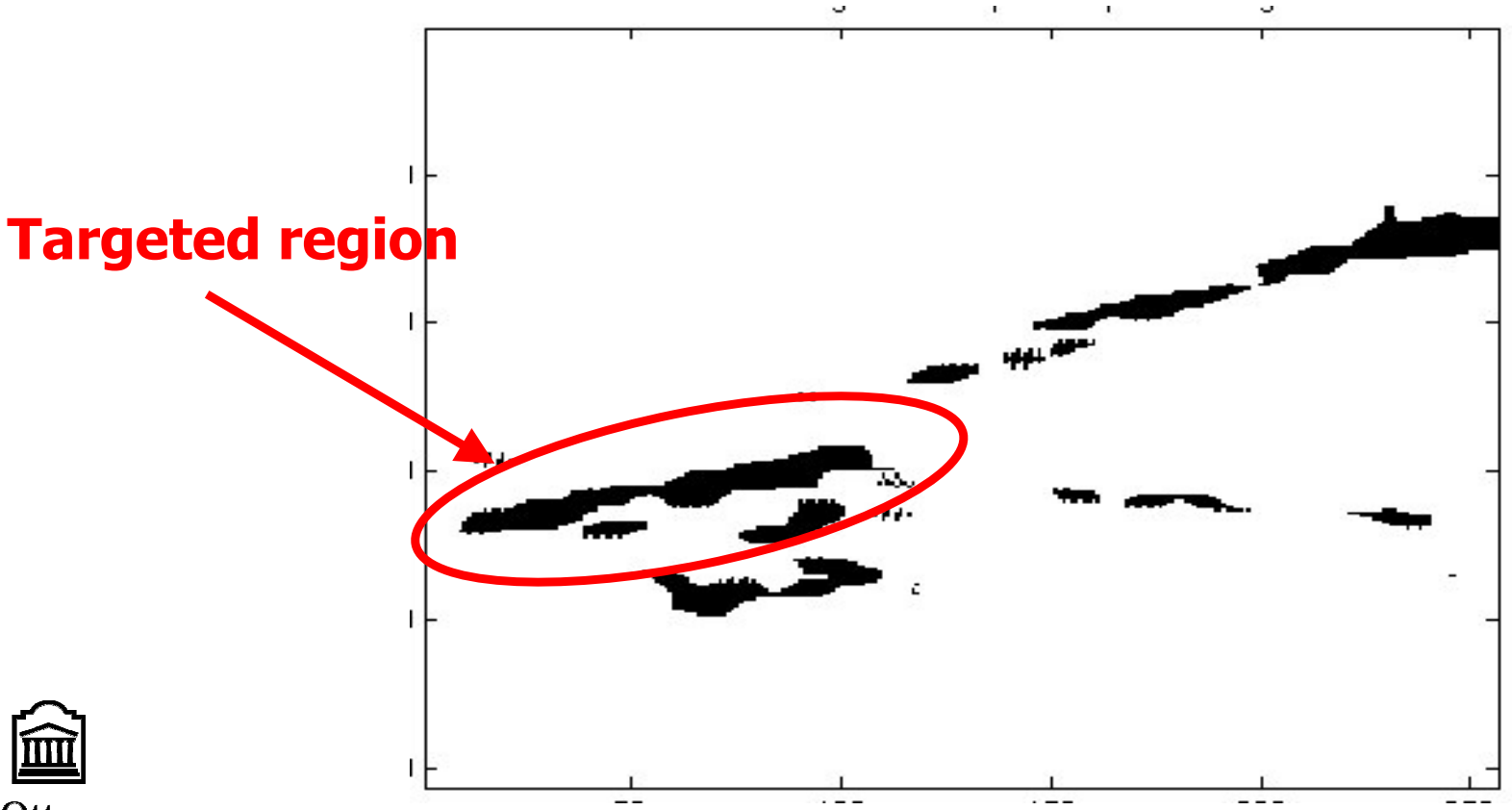




Enhancement result

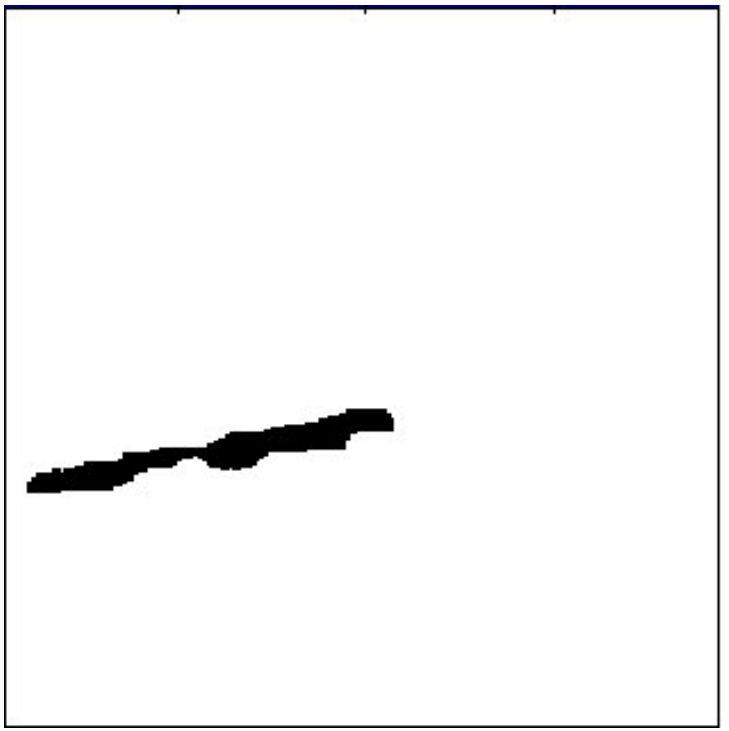
Region Subtraction

- Removes all large regions and keeps only fine details



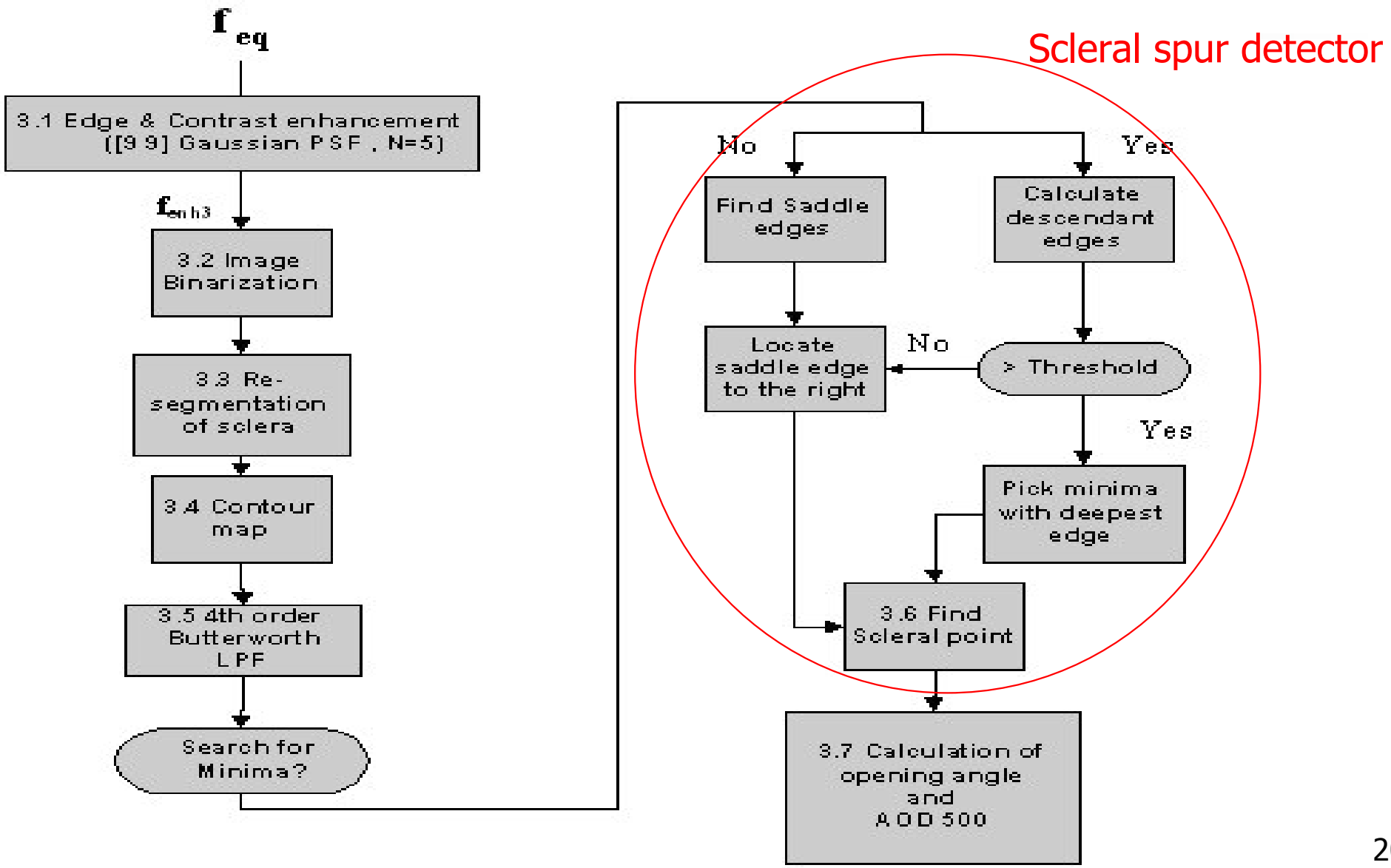
Sclera region classification and segmentation

- 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**



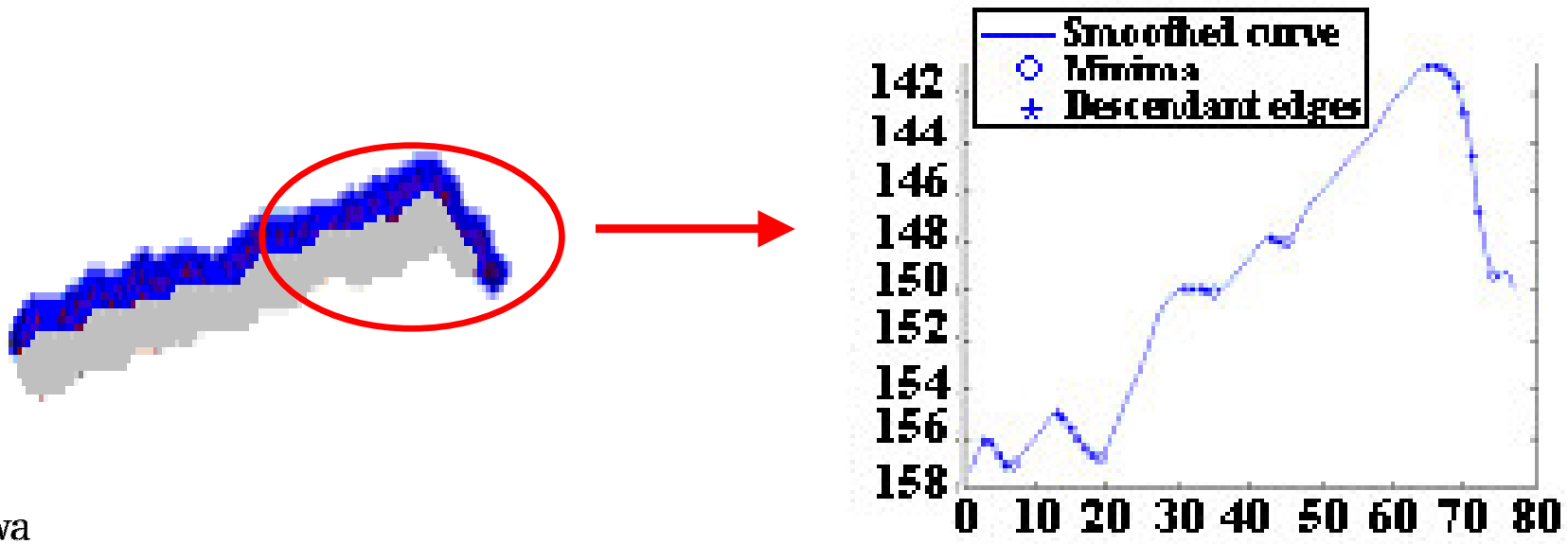
Step 3

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



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 Δ_{edge} of each edge prior to a minimum. The largest Δ_{edge} is chosen to compute the scleral spur coordinate

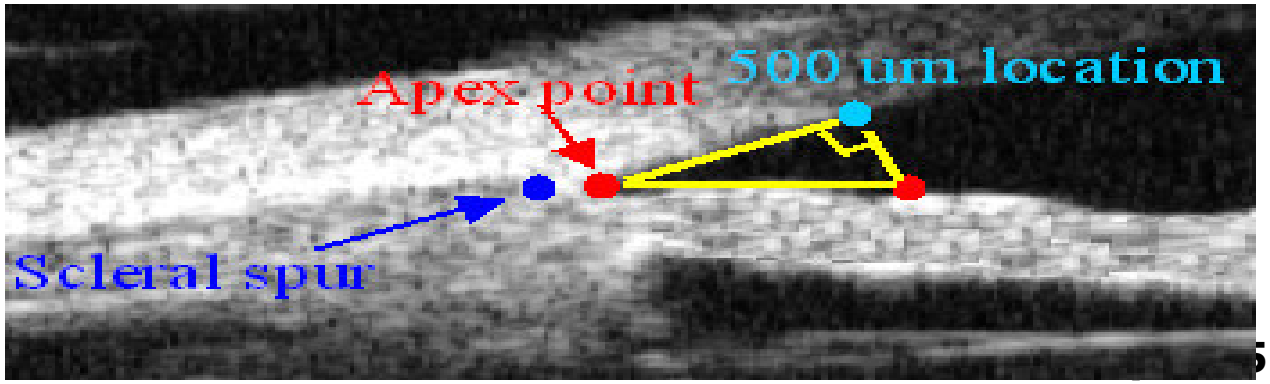
  - **No minima**: Select the saddle edge located most to the right of the 1-D outline

Determination of Measured Parameters

- Clinical parameters:

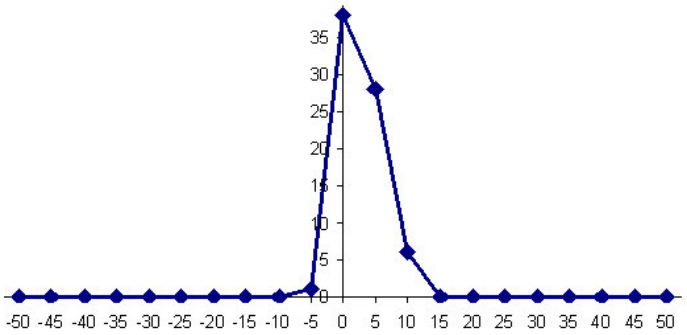
  (1) Open-angle exists if the 500 um point is located to the right of the Apex point

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

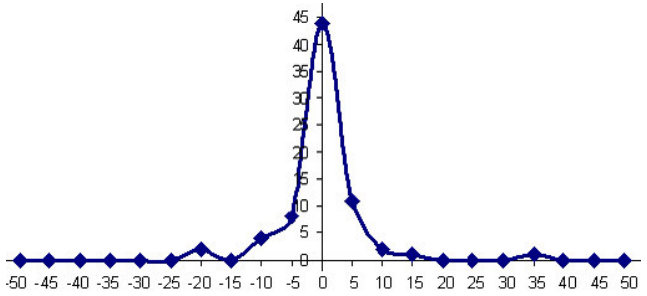


Outcomes of Algorithm

Scleral Spur Pixel offset error



Horizontal direction



Vertical direction

(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

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%