Computer Vision and the Eye:
Determining Intraocular Pressure from Frontal Eye Images

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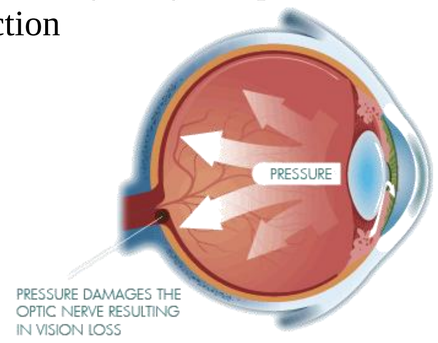
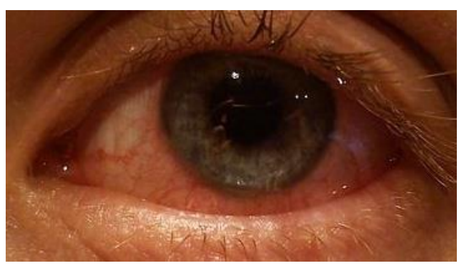
Abstract

INTRODUCTION: Glaucoma, the silent thief of vision, is mostly caused by the gradual increase of pressure in the eye which is known as Intraocular Pressure (IOP). An effective way to prevent the rise in eye pressure is by early detection. Prior computer vision-based work regarding IOP rely on fundus images of the optic nerves.
OBJECTIVE: This paper provides a novel computer vision-based framework to help in the initial IOP screening using only frontal eye images.
METHODS: The framework first introduces the utilization of a fully convolutional network (FCN); as an instance of deep learning; on frontal eye images for sclera and iris segmentation. Using these extracted areas, six features that include mean redness level (MRL) of the sclera, red area percentage (RAP), Pupil/Iris diameter ratio and three sclera contour features (distance, area and angle) are computed.
RESULTS: A database of images from the Princess Basma Hospital is used in this work, containing 400 facial images; 200 cases with normal IOP and 200 cases with high IOP. Once the features are extracted, two classifiers (support vector machine and decision tree) are applied to obtain the status of the patients in terms IOP (normal or high). The overall accuracy of the proposed framework is over 97.75% using decision tree.
CONCLUSION: The novelties and contributions of this work include introducing a fully convolutional network architecture for eye sclera segmentation, in addition to scientifically correlating the frontal eye view (image) with IOP by introducing new sclera contour features that have not been previously introduced in the literature from frontal eye images for IOP status determination.

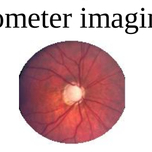
Glaucoma and Intraocular Pressure

- Glaucoma is a disease causing blindness, generally due to increased ***Intraocular Pressure (IOP)***
- Optic nerve is affected
  - Vision is reduced, or totally lost
- The only way to prevent blindness from Glaucoma is through early detection





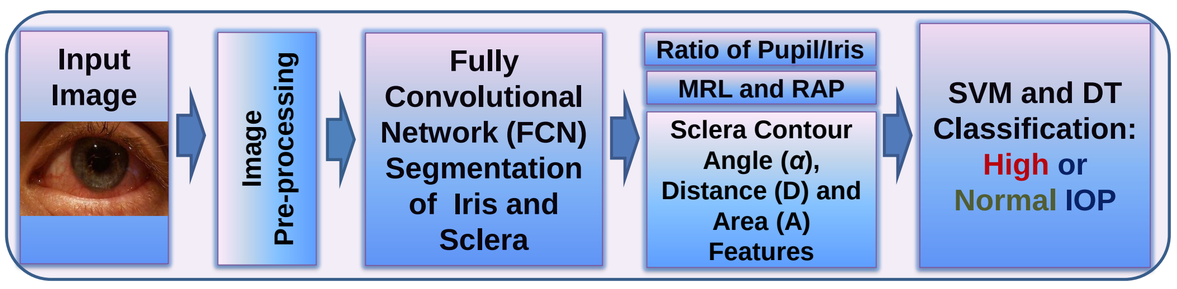
- Traditionally, patients undergo eye examinations on a regular basis at eye clinics to determine IOP and risk of Glaucoma [1],[2]
  - OCT, Visual Field, Tonometry Gonioscopy, Pachymetry and Ophthalmoscopy Tests
    - Ophthalmologist's intervention
      - Eye drops
    - Cumbersome, manual procedure
- Fundus images with optic nerves
  - Requires micrometer imaging



Glaucoma Research Foundation: www.glaucoma.org

Proposed Methodology

- An IOP risk assessment framework is introduced based on deep and machine learning instances of computer vision using solely frontal eye images. Six features are extracted from segmented eye regions using a Fully Convolutional Network (FCN): Pupil/Iris diameter ratio, Mean Redness Level (MRL), Red Area Percentage (RAP) of the sclera, in addition to Area, Distance and Angle of the sclera contours [1].



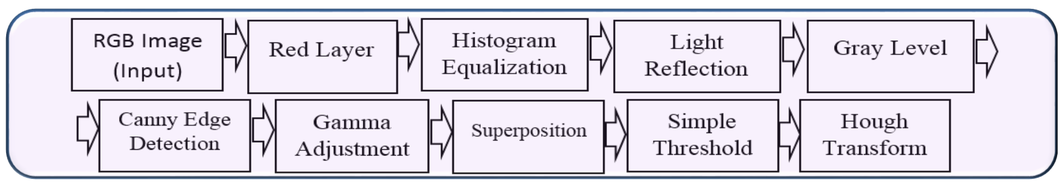
IOP risk assessment framework

- ✓ Computer vision techniques applied on frontal eye images
  - Image pre-processing and circular hough transform (CHT)
  - FCN structure: Convolution, Deconvolution, Activation and MaxPooling
  - Sclera and iris segments along with triangle formulations for feature extraction
  - Support Vector Machine (SVM) and Decision Tree (DT) classification
- ✓ Ordinary camera (smartphone camera) can be used
- ✓ Non-contact, Non-invasive
- ✓ Automatic

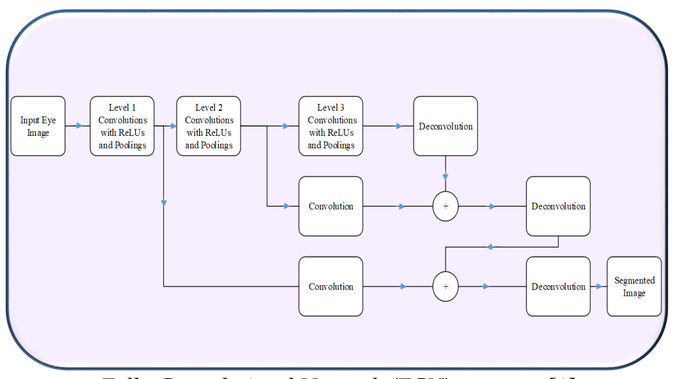
Database

- Image database (DB) from the Princess Basma Hospital [1],[3]
  - 400 participants: 244 male and 156 female, between 40 - 65 years old
    - 200 subjects with high eye pressure (22-30 mmHg) including 6 cases with Glaucoma
    - 200 subjects with normal eye pressure (11-21 mmHg)
  - Images were taken 20cm from the patients with consistent lighting
  - IRB approval obtained at Princess Basma Hospital for the human subject samples.
    - Authors formally requested access to the dataset

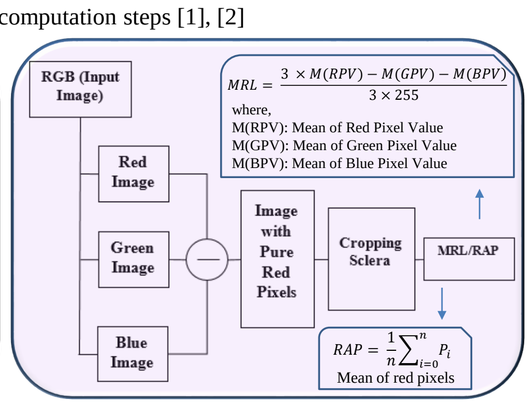
Image Analysis



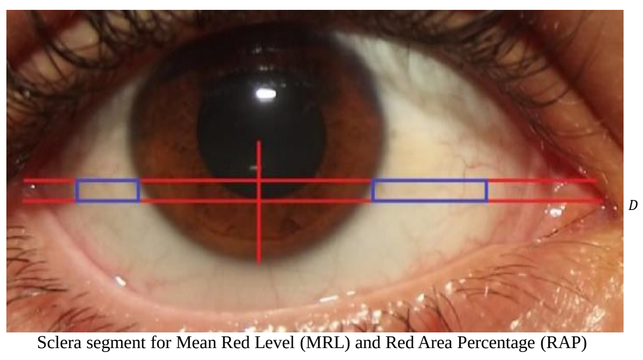
Pre-processing and Pupil/Iris diameter ratio computation steps [1], [2]



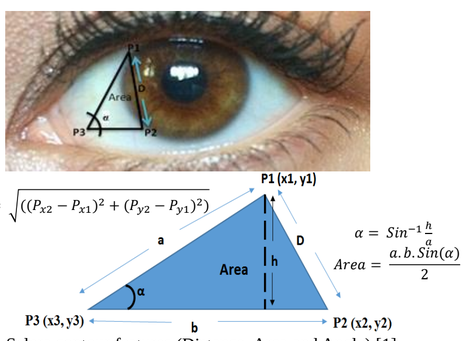
Fully Convolutional Network (FCN) structure [1]



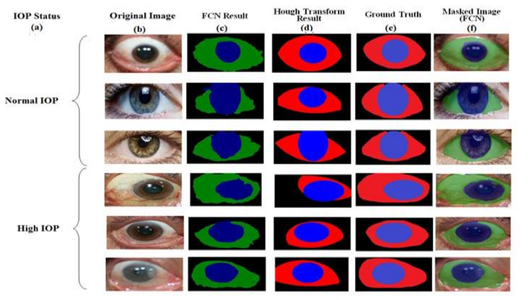
MRL and RAP computation steps [1], [3]



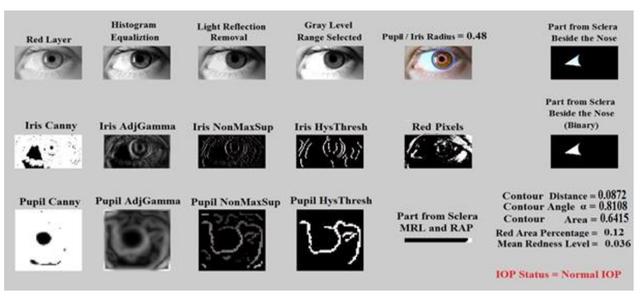
Sclera segment for Mean Red Level (MRL) and Red Area Percentage (RAP)



Sclera contour features (Distance, Area and Angle) [1]

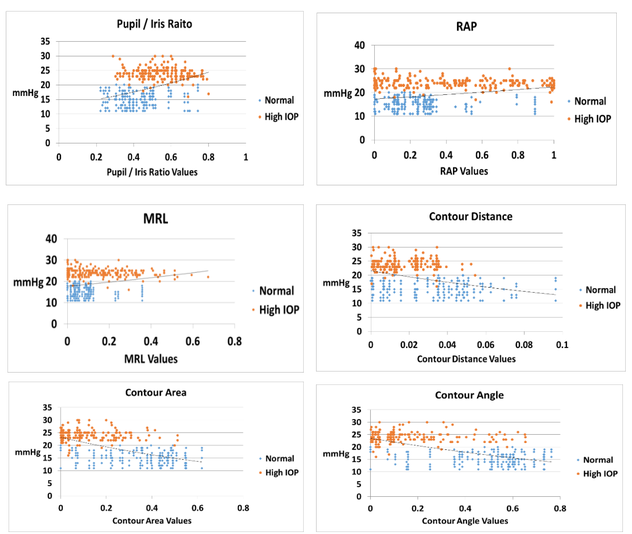


Fully Convolutional Network (FCN) for sclera and iris segmentation



IOP status determination steps

Results and Outcome



Relationship between IOP and the six extracted features

OVERALL CONFUSION MATRIX FOR DT

		Normal	High Pressure	
Output class	Normal	196	5	
	High Pressure	4	195	
		TARGET CLASS		
	Accuracy	98.0%	97.5%	Overall Acc.: 97.75%
	Error	2.0%	2.5%	Overall Err.: 2.25%

Sample High IOP case

Results show evidence of computational relationship between the proposed frontal-eye view features and IOP for high classification accuracies. Pupil/Iris, MRL and RAP are directly proportional to IOP while the sclera contour's area, distance and angle features are inversely proportional to IOP. The proposed ideas may eventually be implemented on smartphones for personalized IOP screening [4], [5], [6]. The information can aid in the automatic early detection of high IOP and Glaucoma, in an effort to circumvent the onset of blindness.

References, Published Work and Grants

[1] M. Aloudat, M. Faezipour and A. El-Sayed, "Automated Vision-Based High Intraocular Pressure Detection Using Frontal Eye Images", *IEEE Journal on Translational Engineering in Health and Medicine (IEEE J-TEHM), Vol. 7, No. 1, Article No. 3800113*, pp. 1-13, 2019.
[2] M. Al-Oudat, M. Faezipour and A. El-Sayed, "A Smart Intraocular Pressure Risk Assessment Framework Using Frontal Eye Image Analysis", *EURASIP Journal on Image and Video Processing, 2018: 90, pp. 1-15, Springer*, Dec. 2018.
[3] M. Aloudat and M. Faezipour and A. El-Sayed, "High Intraocular Pressure Detection from Frontal Eye Images: A Machine Learning Based Approach", *in Proceedings of the IEEE International Engineering in Medicine and Biology Society Conference, (IEEE EMBC'18)*, pp. 5406-5409, Jul. 2018.
[4] M. Faezipour and A. Abuzneid, "Unveiling Intraocular Pressure from Frontal Eye Images: A Computer Vision-Based Approach", *submitted to AWS Amazon Faculty Research Awards (ARA)*, 2020.
[5] M. Faezipour and A. Abuzneid, "Intelligent Computer Vision Sensing of the Eye: Can Frontal Eye Images Reveal Intraocular Pressure?", *submitted to Sony Research Award Program*, 2020.
[6] M. Faezipour, "Histogram Analysis for Automatic Blood Vessels Detection: First Step of Intraocular Pressure (IOP)", *University of Bridgeport Seed Money Grant, Funded*, 2015-2016.

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