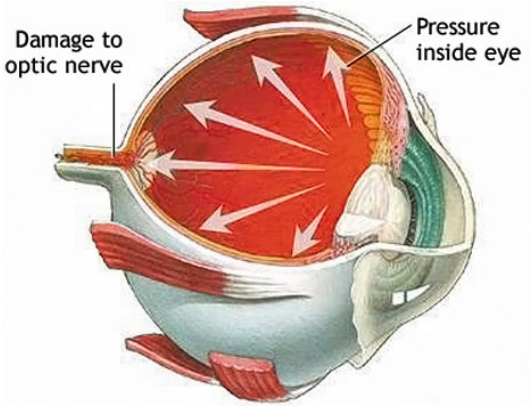
Motion pattern-based Image Features for Glaucoma Detection from Retinal Images

K Sai Deepak, Madhulika Jain, Gopal Datt Joshi and Jayanthi Sivaswamy

CVIT, IIIT Hyderabad, India

Agenda

- **Glaucoma Detection**
  - Visual Symptoms of Glaucoma
- **State of the art in Glaucoma Detection**
  - Segmentation based method Detecting Glaucoma
  - Global Features for Detection
- **Proposed Method**
  - Image Representation: Generalized Moment Pattern (GMP)
  - GMP for Glaucoma Detection
- **Experiments**
  - Dataset
  - Results

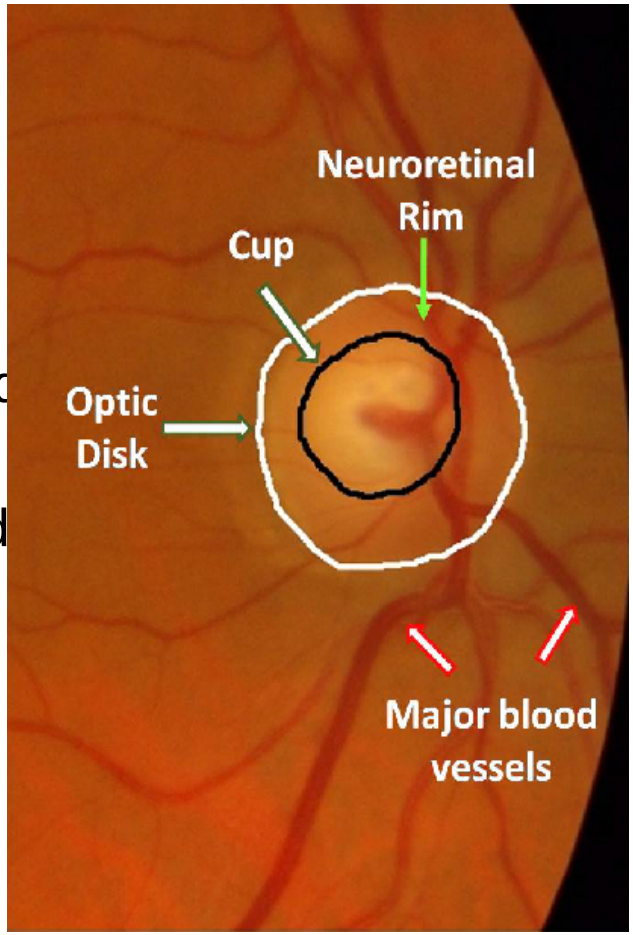


Glaucoma Detection

- Glaucoma is an eye disorder that causes irreversible loss of vision
  - affects the Optic Nerve in retina

- In a retinal image, the region of interest is the Optic Disk (OD)
  - **Disk** – is marked by the outer bound OD (white)
  - **Cup** – is marked by the inner bound OD (black)

- *Glaucoma* manifests as structural deformations in OD



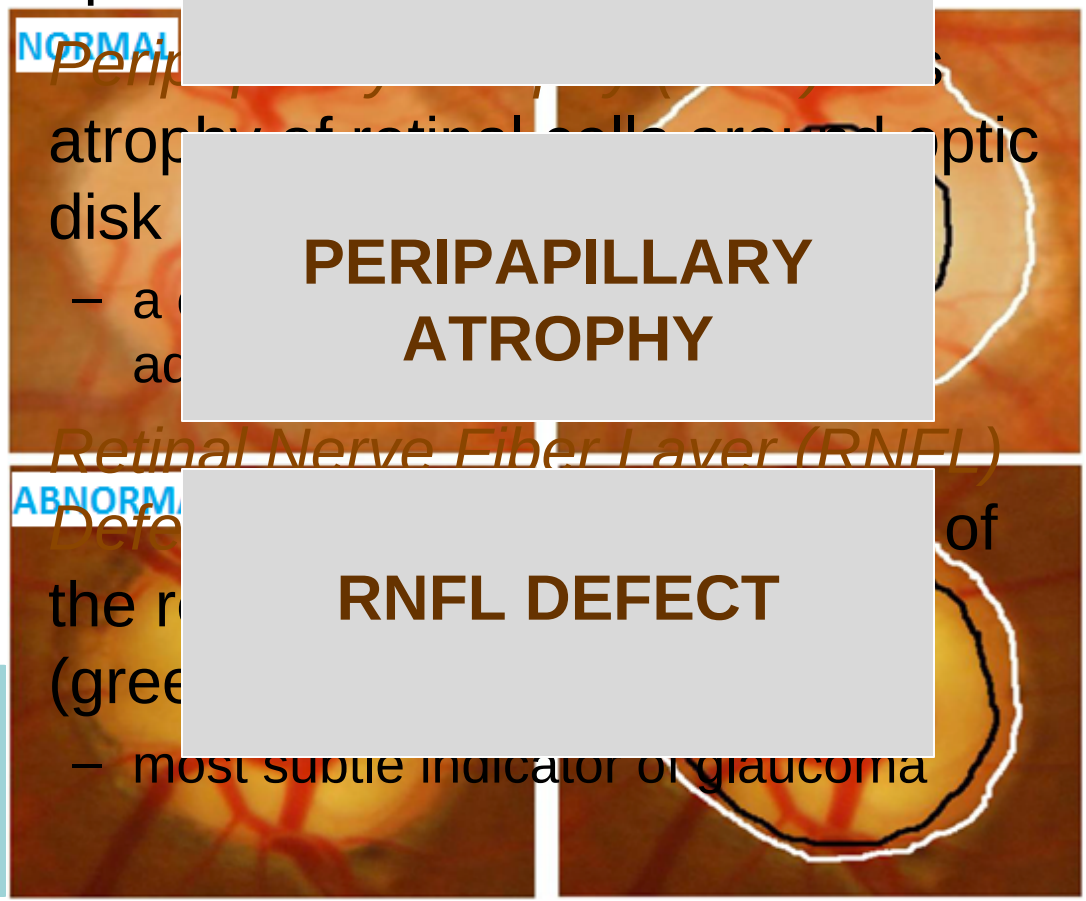
Visual Symptoms of Glaucoma

- *Rim*
  enlar t to optic
- *Peripapillary Atrophy (PPA)*
  atrop optic disk
  - a
    ac
- *Retinal Nerve Fiber Layer (RNFL) Defe* of the r
  (gree
  - most subtle indicator of glaucoma

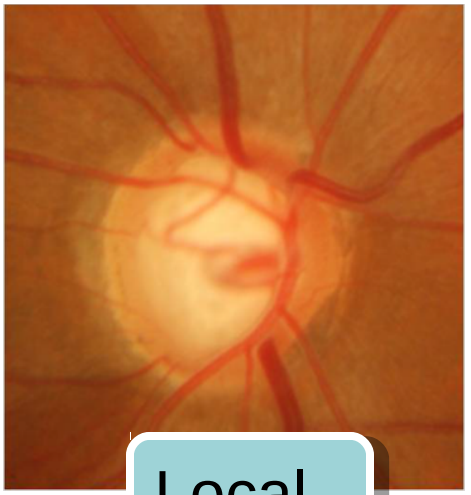
RIM THINNING

PERIPAPILLARY ATROPHY

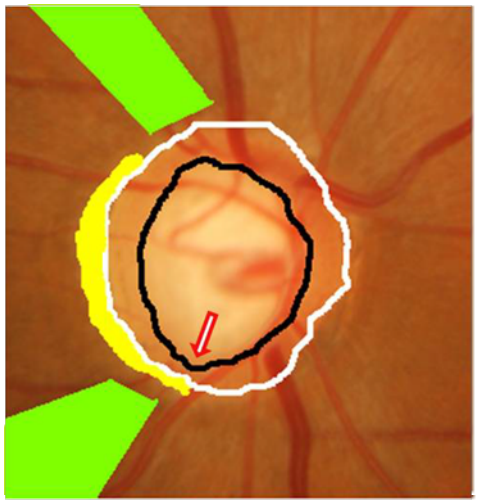
RNFL DEFECT



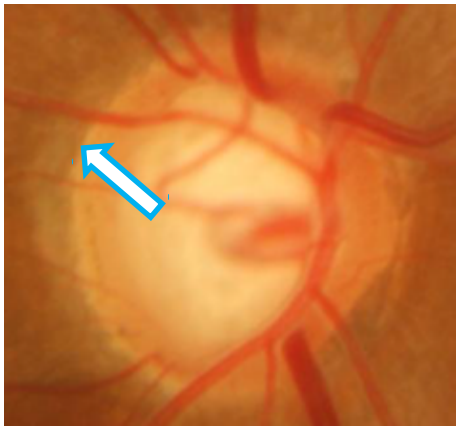
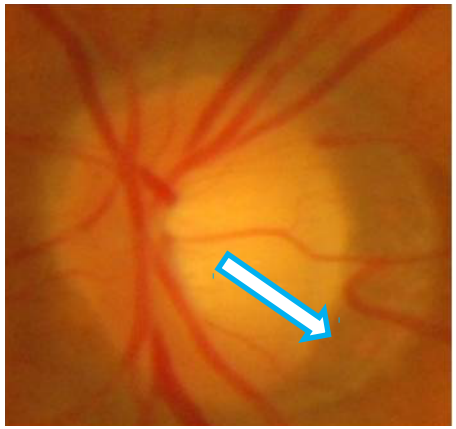
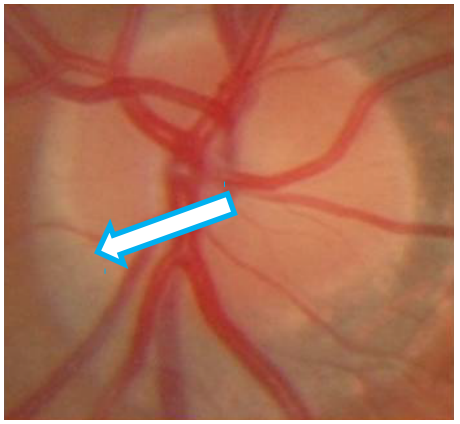
Global



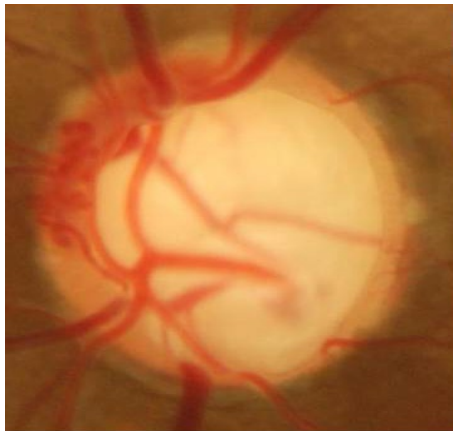
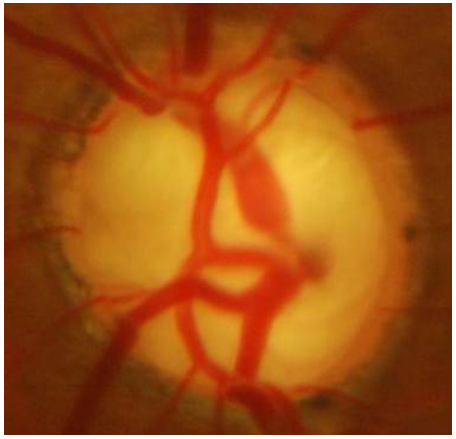
Local



More Examples of Atrophy

More Examples of rim thinning

Glaucoma Detection – Background

Local Approaches

Aim at **measuring the cup to disc ratio** after segmenting the cup and disk regions

- *Joshi et al. (2011)*
  - Chan Vese model (CV model) with no shape constraints to segment disk
  - R-bends (relevant bends) and pallor information for cup segmentation
- *Liu et al. (2009)*
  - level set method followed by ellipse fitting for disk segmentation
  - level set based cup region segmentation followed by ellipse fitting

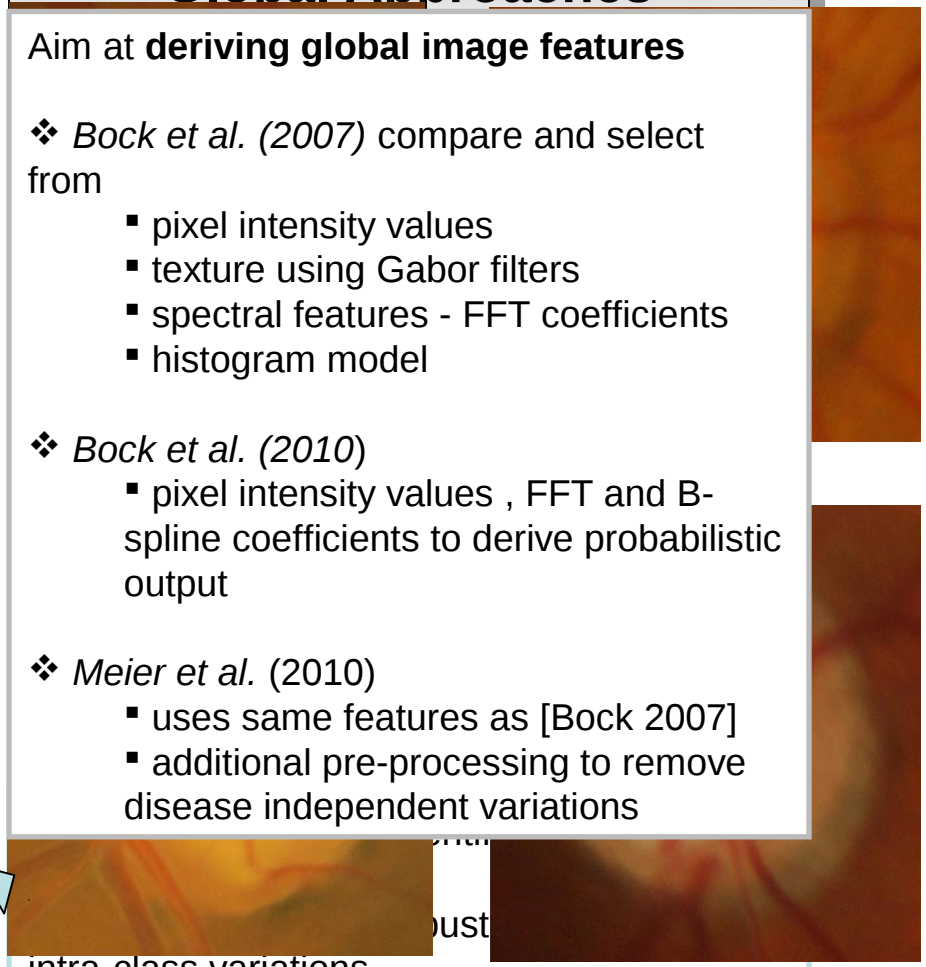
+ Morphological changes (rim thinning) are captured well, provided segmentation is accurate

− Accurate identification of these ill-defined boundaries is a difficult task

Global Approaches

Aim at **deriving global image features**

- *Bock et al. (2007)* compare and select from
  - pixel intensity values
  - texture using Gabor filters
  - spectral features - FFT coefficients
  - histogram model
- *Bock et al. (2010*)
  - pixel intensity values , FFT and B-spline coefficients to derive probabilistic output
- *Meier et al.* (2010)
  - uses same features as [Bock 2007]
  - additional pre-processing to remove disease independent variations



ust

intra-class variations

Challenges

- Encode *subtle local deformations* in anatomical shape
- Robustness to *subtle changes in intensity distribution*
- *Availability of annotated data*

Our Strategy

- To encode global and local image variations in a unified way
- To learn the ‘normal’ cases and detect glaucoma as a deviation from normal

Our Proposal

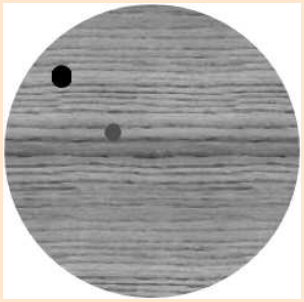
Leverage a *novel Image Representation*

Our approach for Glaucoma Detection

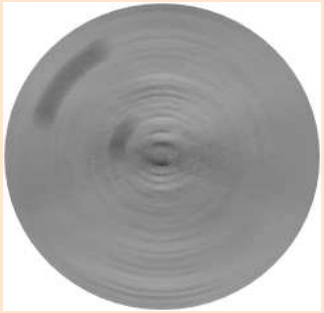
- Leverage the GMP image representation proposed in [*Deepak et al 2012*] for abnormality (bright lesion) detection
  - Derived by inducing motion to a given image

- Modify and extend this representation for handling abnormalities in the form of *structural deformations*

Review of the GMP representation



On rotation



Original Image
- Dull and dark objects on a textured background

Result

Rotation serves to

- Blur the background
- Smear and extend the objects (lesions)

Tuning parameters

- Rotation step and extent
- Coalescing function

GMP for Glaucoma Detection

Model of Optic disc as a bright circle (cup) with a grey surround

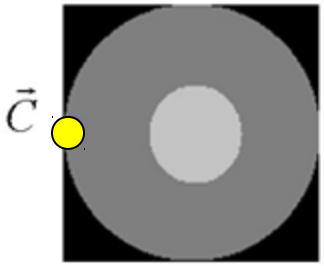
Normal case

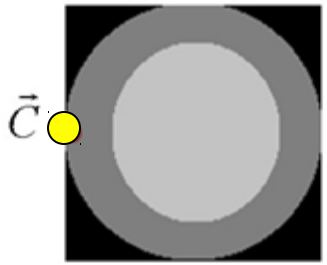
Global

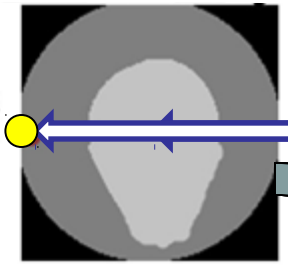
Local

With rim thinning

Selection of Pivot Point

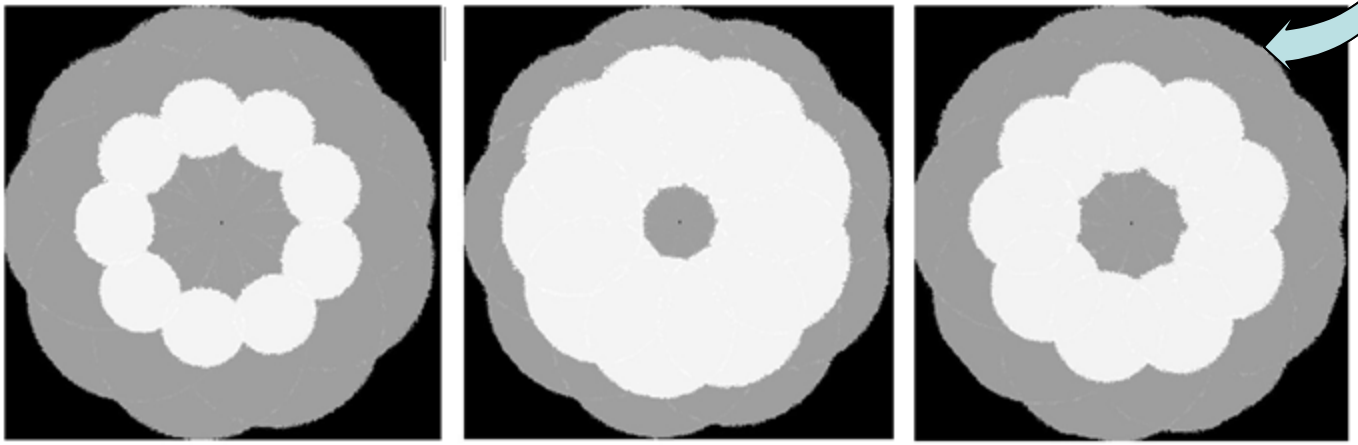






Shifting the pivot to the periphery

On rotation



Abnormality is accentuated

GMP for Glaucoma Detection

Given I, its GMP-based representation is

Coalescing function

$$I_{GMP}(\bar{p}) = \max_{n=[0\ldots(N-1)]} R_{\theta_n}\left(I\left(\bar{p}-\bar{c}\right)\right)$$

$\bar{p}$ denotes a location in I; c is the pivot location

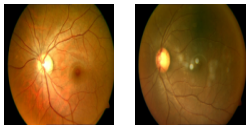
R_θ is a rotation matrix

n is the number of frames generated by applying rotation

$\theta_n = n\theta_o$ denotes the extent of rotation in the nth frame, $N = \frac{360^o}{\theta_o}$

$$I^{m\times m} \overset{R_{\theta_n}}{\Rightarrow} I_{\theta_n}^{2m\times 2m}$$

Glaucoma detection - Workflow



Normal images

New image

Pre-processing

Generate GMP

Feature Extraction

Learn Normal Class

Normal Sub-space

Detect Glaucoma

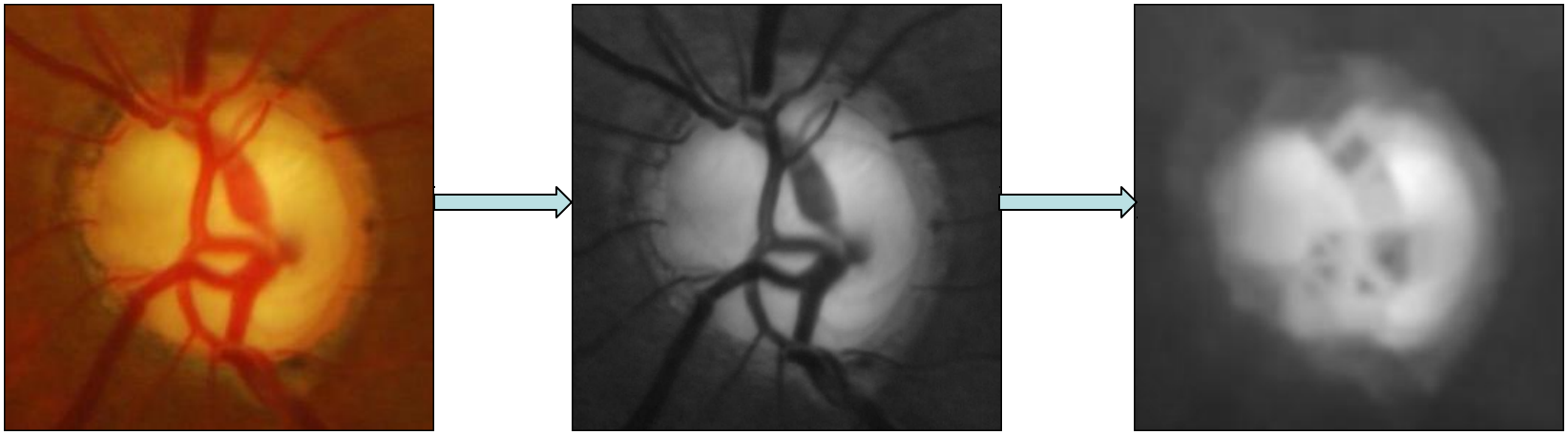
Normal

Glaucomatous

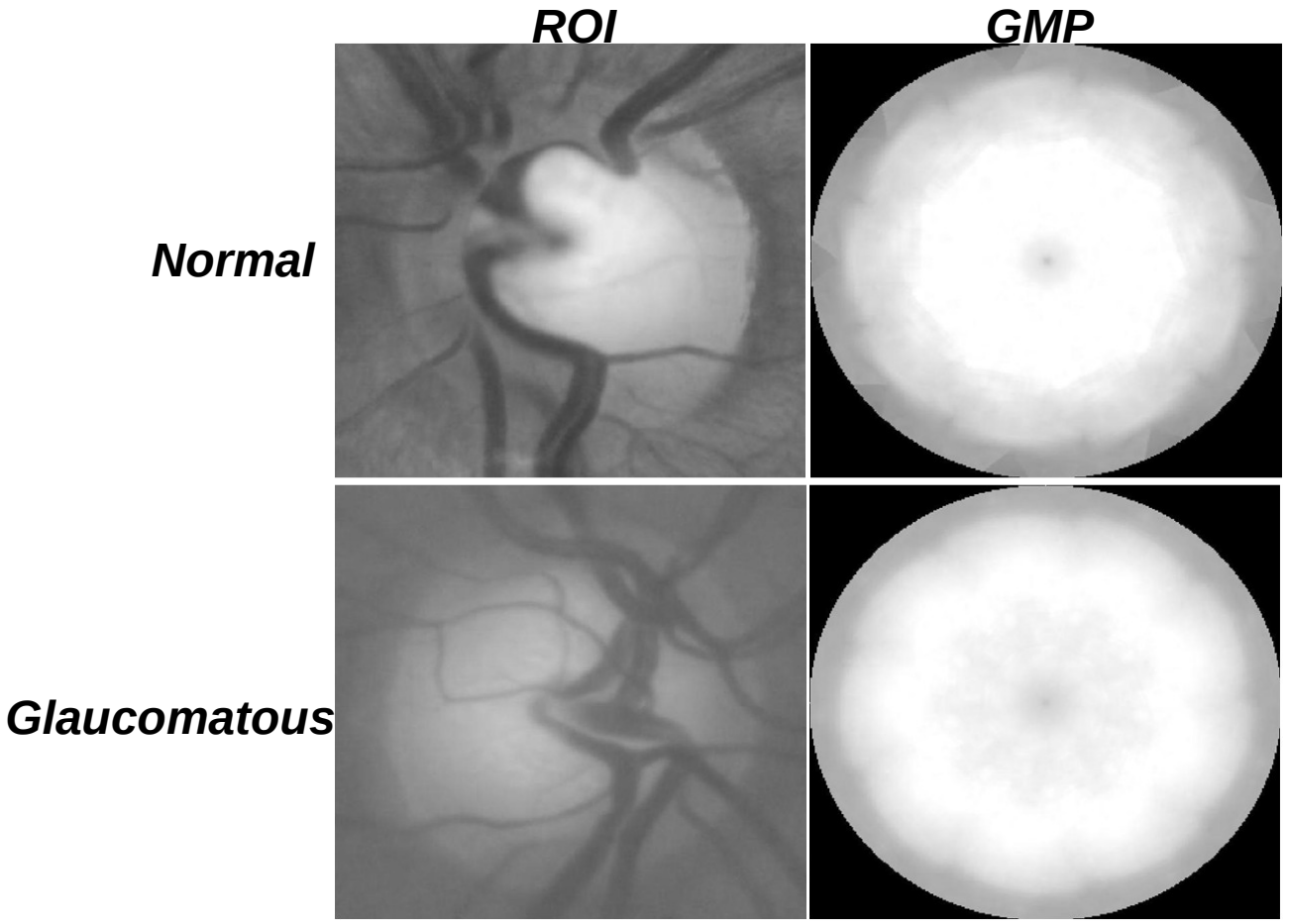
Pre-processing

Given a retinal image

1. Extract a region of interest around the optic disk [7]
   - the green channel is used for further processing
1. Generate a vessel-free image by roughly segmenting the blood vessels and suppressing them using in-painting [8]



GMP for retinal images



Rotation step: 40˚; Extent of rotation: 360˚

Feature Extraction

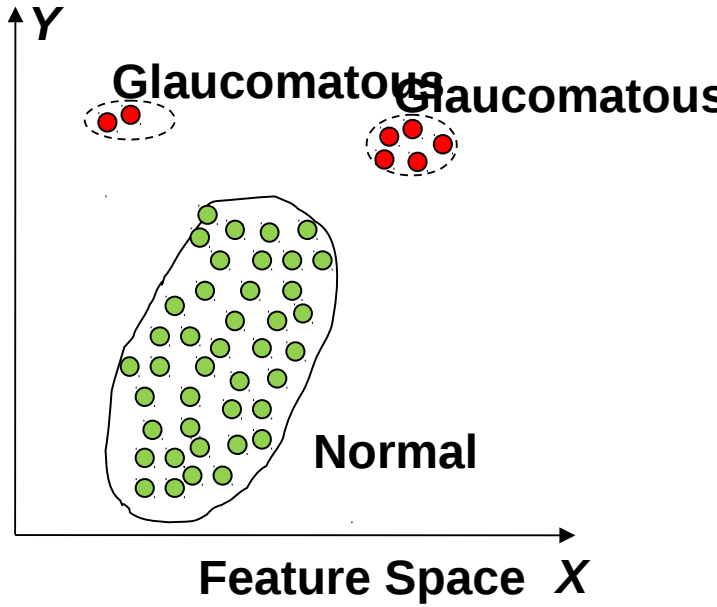
Two features were considered:

- Radon Transform Based Descriptor
  - GMP is projected in several directions and the results are concatenated to create a feature vector

- Histogram of Intensity Clusters (HIC)
  - An intensity based clustering is performed for all GMP responses using k-means algorithm
  - A histogram of intensities for each ROI corresponding to these clusters is used as the feature vector

Classification

- Deviation from Normal is considered as Glaucomatous
- Feature vectors are used to construct the normal subspace
- Classification is based on Principal Component Analysis Data Description (pca-dd) [1]
  - Feature vectors are projected to D-dimensions and reconstruction error is computed
  - A threshold on the reconstruction error is applied for glaucoma detection



Experiments and Results

DATASET

- 1186 images from 596 patients
  - Each image were marked by 3 experts as Normal, Suspect, Confirmed
  - A gold standard was found using *majority* voting

Distribution (Gold Standard)

Normal	Suspect	Confirmed
624	234	328

Set 1 – Three classes (Normal, Suspect and Confirmed)

Set 2 – Two classes (Normal and Confirmed)

Experiments and Results

PARAMETER VALUES	
GMP	
Feature Vectors	**RTD** • 6 projections (α = 0^o,30^o,60^o,90^o,120^o,150^o) • Each projection is averaged to generate 6 bins • Resultant feature vector of length 36 **HIC** • k= 6 is used for k-Means clustering
Classifier	• Feature vectors are projected to D=6 dimensions • Multiple thresholds are applied on reconstruction error to compute classification performance

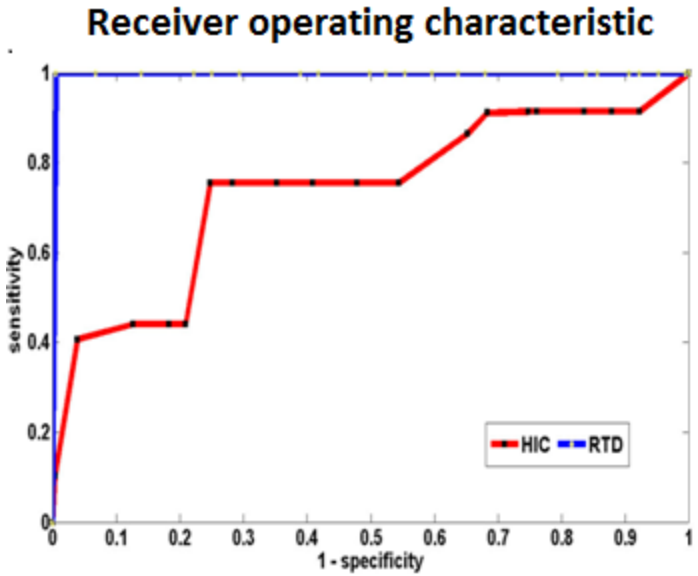
Classification Performance

Training set :

324 Normal

- Set 1
- Set 2
  - 862 images: 300 normal, 234 suspect, 328 confirmed cases
  - 628 images: 300 normal, 328 confirmed cases

Descriptor	Sensitivity	Specificity	Area under ROC
RTD	0.97 1	0.87 0.98	0.96 0.98
HIC	0.84 0.95	0.67 0.78	0.81 0.7



Comparison against related Method

Method	No of Images	Sensitivity	Specificity	Area under ROC
Proposed (RTD)	**952**	**1**	**0.98**	**0.98**
Bock et al. [4] Global feature-based method	**575**	**0.73**	**0.85**	**0.88**

Conclusion

- A global-feature based approach was proposed for glaucoma detection from retinal images
- The Generalized Moment Pattern representation was *extended for detecting structural deformations* in Optic Disk
- Evaluation of glaucoma detection on a large retinal image dataset establishes the method is successful
  - Even *suspect (subtle)* cases of glaucoma are detected successfully

References

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[8] G. D. Joshi, J. Sivaswamy, K. Karan, and S. R. Krishnadas. Optic disk and cup boundary detection using regional information. In *IEEE International Symposium on Biomedical Imaging* (ISBI), pages 948-951, 2010.

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