IMPROVEMENT IN KERATOCONUS DIAGNOSIS USING MORPHO-GEOMETRIC VARIABLES WITH RNN NETWORKS

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Abstract: There is an eye disease called Keratoconus (KC) which has potential to cause visual acuity loss; hence, it can be considered as disability due to its severity. There are some limitations in current method in detecting cornea region's boarder edge. Primary objective for the paper need to identify the structural description of disease' asymmetry with the help of Morpho-geometric parameters relates with the keratoconous eyes along by means of slight visual control. It also includes the application of Recurrent Neural Network (RNN) analysis which is sort of Neural Network in which previous step's output are sent to present step as an input. In order to determine most prominent correlation, Stepwise Discriminant Function Analysis is used in analyzing output. The Prominent correlation was identified between thinnest point in the anterior deviation and thinnest point in the posterior deviations of minor keratoconic cases. MATLAB R2014 software is used to implement the framework and analyses of simulation results were performed.

Keywords: RNNs, Keratoconus, Discriminant Function Analysis, morpho-geometric parameters.

1. Introduction

Keratoconus be a kind of different eye disease which leads cornea thinning; Cornea is referred to front surface of the eye and this disease contracts the cornea and changes it into a cone-like shape. Changed vision caused by Keratoconus causes cannot be corrected with eyeglasses. These Keratoconus cases mostly occur during person's teen age of his early 20s.

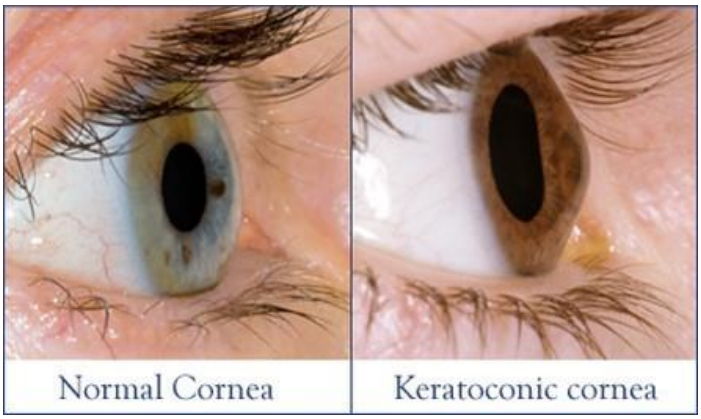

Fig. 1 Keratoconus eye diseases

Irregularities of Cornea affected eye's shape are shown in Fig.1; it leads to developing nearsightedness and development of asymmetrical astigmatism, also creates more problems like blurred vision and distorted vision. Keratoconus also causes light and Glare sensitivity in the eyes. Based on the recent research, keratoconus occurs due to corneal tissue weakening and also imbalance in cornea enzymes could also be the reason for the disease.

Due to the imbalance of the enzymes, cornea becomes more vulnerable to oxidative damage from compounds which are referred to free radicals; this process weakens and bulges forward. This oxidative damage and cornea weakening could include a genetic predisposition which makes keratoconus frequently affects more members in the same family. More exposure to UV rays from sun, extreme rubbing of eyes, improper fixing of contact lens and irritation of chronic eye could also be associated with Keratoconus.

Keratoconus is a corneal disease which causes progressive distortion of the curvature of the corneal that in turn affects patients' visual health. The cornea's geometric feature in pathology which should contain final pathway of common among genetic, molecular and environmental factors which define the pathology's origin and its evolution has been analyzed and considered below a total method. But, a disease beginning is limited owing toward the improvement of abnormalities of structural generated by

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collagen fibers irregular organization in a stroma region and due to reduction in collagen fibrils anchoring capacity in the Bowman layer [1]. David Xu et al., 2014 proposed the segmentation began from the frame having the largest mean image intensity for approximation of the corneal apex location. Neighbor frames afterwards were processed. To reweight current graph edges results obtained from previous frame were utilized to favor for segmenting of same shape and location to old result [2]. Mean ± SD age would be 24.12 ± 6.80 yrs in group of minor – moderate Keratoconus, 22.80 ± 8.06 yrs in subclinical and 25.29 ± 5.37 yrs in volunteers of normal conditions. There was no apparent difference in distribution of age in between the groups. In comparison with our results, values of keratoconus group were found lower. This difference in value could be referenced to various severities of Keratoconus in the subjects that are participating in the two above said studies [3].

The largest forward movement and greatest dioptric values were generated when eccentric thinning was combined with lower modulus, and it is inferred that both involve in an intricate relationship in the keratoconus pathogenesis. Also, the elevation maps posterior corneal analysis revealed the keratoconus in subjects having lower values of corneal thickness however with elevation maps of anterior corneal same as to those experimented in corneas of normal people. A corneal curvature geometric decomposition or progressive distortion from a point of singular designated the apex of corneal [4]. A spatial side view decomposition of pachymetry that is defined as an annular enhanced/reduction for the thickness from a point of singular called the points of minimum thickness. Aberrations Posterior and spatial profile data of thickness did not obviously enhance ability of discriminative over that of wave front data of anterior alone, application of Linear discriminant analysis (stepwise) was used by utilizing approach of two groups, to develop metrics with input data from obtained from the posterior and anterior surfaces and received from pachymetry. The step-by-step method was used to identify the least possible independent variables mandatory for correct classification. This paper recommends the corneal thickness analysis which disclosed that regular corneas have had more central value and values of paracentral. Higher differences were observed between the entire cornea's thinnest site and keratoconic corneas paracentral areas compared to regular cornea [5]. The protrusion of cone-shaped was detected in posterior and anterior elevation maps of corneal of one subject however to appeared only in elevation map of posterior of other keratoconus subject. The suggested approach utilizes the features of the Cornea to identify the measurement of points that are determined in both surfaces apex of corneal and least thickness points. Next section (2) describes literature survey, third section (3) explains about detection procedure of Keratoconus and analytic method. The section 4 deals with techniques of machine learning employed for processes of detection. The last section (5) describes about the results and discussion and finally on the conclusion.

2. Related Works

Ahmad R. Dhaini et *al*.,2018 [6] recommended that the first approach which employs analysis of image and machine learning , which able to detect and calculate haze of corneal, presence of separation stripe like demarcation line and its intensity in OCT images automatically. The programmed approach gives the consumer with data of haze and visual annotation method, which reflects the haze shape and haze position and existence of demarcation line in the area of cornea. Tianqiao Zhang et *al*., 2017 [7] suggested segregating stage of processing stage in previous level into four different steps: resizing of image, approximation of apex near the corneal the lateral organization points, approximation of epithelial apex's axial coordinate and horizontal artifact suppression. A unique feature is to be extracted in three different steps: ROI (region of interest) derivation of layer over the interfaces, attend ROI of edges would be mostly horizontal and edge detection which is customized.

Xuejun Qian et *al*., 2018[8] recommended that the raising of corneal rigidity and also the linked with the cross volume changes subsequent to cross linking of formalin with observed exactly in ARFI images which is referred from Young's modulus that is reconstructed meanwhile structural images of B-mode are almost unaltered. Additionally, the relationship of cornea stiffness with IOPs was investigated and this is done for corneas of twelve porcine. The value of corneal stiffness is considerably dissimilar at multiple IOPs and has a potentiality to get stiffer with increased IOP. Masoud Safarzadeh et *al*., 2016 [9] suggested the acquiring measurement of radius curvature by system in smooth and sheer meridians with a 3.0 mm-diameter central cornea field. An astigmatism and corneal power were obtained with the help of 1.3375 keratometry refractive index. Corneal Aberrometry be to derive with for help the technique called ray-tracing technique. The apex corneal thickness relate with the thinnest point between the suspected KC eyes were compared with regular unaffected eyes and significant differences were found. F. Nasrin et *al*., 2018 [10] recommended that the ectasia location can be accurately identified by true mean curvature. We propose a quadratic smoothing for spline algorithm for the simultaneously computing distance from the ground maps for corneal surfaces, true mean curvature and pachymetry of anterior and posterior. Single measurement data received from image capturing equipment like Scheimpflug imager or anterior segment optical coherence tomographer will be input to the algorithm.

The profile of epithelial thickness indicated a thinner region of epithelium temporally, in-line with surface apex posterior, that recommended Keratoconus diagnosis[11-14]. However, the epithelium classification function had not classified it as keratoconus. Using linear stepwise discriminant analysis which is proposed in this work can overcome these limitations.

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3. Morpho-Geometric Variables Detection Method

The patient 3D specific model for the cornea in solid works can be applied with the measure some variables like Morpho-geometric that will be used to characterize the cornea which is analyzed. If Keratoconus is left unattended or untreated, it can become serious problem. This can result in severe decline and vision loss. If patients with Keratoconus are detected in early stages, they can have life time quality vision. Various warning signs which can be sensed can help in early detection of the disease[15-16]. Some sample warnings are given below which requires eye care professional consultation:

- Continuous Squinting
- Eyes discomfort
- Frequent Prescriptions changes
- Halos and glare sensitivity
- Ghosting
- Double Vision
- Continuous eye rubbing

Treatment done at the earliest can reduce the Keratoconus progress, and it is found that vision quality is improved by some treatments for those with rigorous vision loss. It is necessary to get your eyes regularly checked which can improve vision quality, if you have Keratoconus in family history. Other conditions like high BP, diabetes and cataracts can be identified during frequent screening. Being aware of warning signs would help in detecting these problems at the earliest. Ensuring you have frequent eye check done by eye care professional which would ensure early identification of Keratoconus and any other conditions of eye.

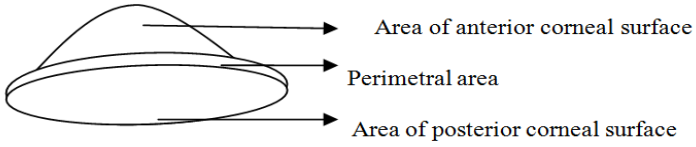

Fig. 2 Characterization of the Cornea

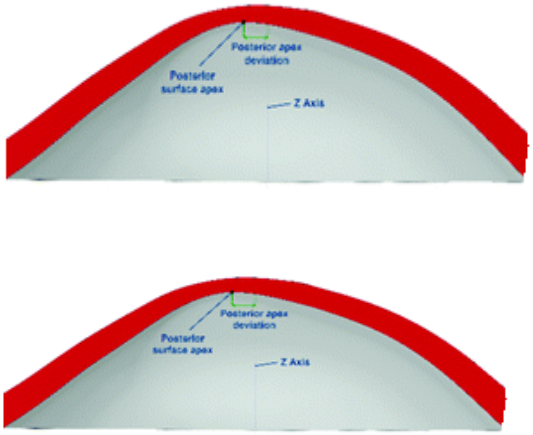

Fig. 3 Cornea Characteristics parameter

Cornea characteristics and characteristics parameters are shown in Fig. 2and 3. Table 1 refers to the parameters.

Table1 1 Morpho-Geometric Variable with the description.

S.No.	Morpho-Geometric Parameter	Acronym variable	Explanation
1.	Corneal Volume(mm^3)	CV	Volume described by the solid model generated
2.	Anterior/Posterior corneal surface area (mm^2)	A_{ant} /A_{post}	Area region of the exterior /interior surface
3.	Corneal surface area (mm^2)	A_{tot}	Total area described by the solid model generated
4.	Posterior sagittal plane apex area (mm)	$D_{antapex}$/$D_{postapex}$	The distance taken from the optical axis to apex of the anterior/posterior corneal surfaces
5.	Sagittal plane area at minimum thickness point (mm^2)	$A_{postmet}$	Area of the cornea within the sagittal plane passing through the optical axis and minimum thickness point of the anterior /posterior corneal surfaces

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6.	Central of mass X,Y,Z (mm)	CMx/CMy/CMz	The mass coordination at the center taken as the X,Y,Z of the solid

The primary objective measure of this work intended to define the model which follows keratoconic cornea (KC) which has minor visual loss with corneal deformation. Correlation coefficients, specificity and sensitivity are secondary outcome of new method of KC detection. Posterior apex deviation mean value (0.19 +/- 0.10 mm) in the KC group was more than anterior apex deviation's mean value (0.01 +/- 0.02 mm). Meanwhile minimum thickness point of posterior and anterior curvatures have value of 1.04 +/- 0.45 mm and 1.11 +/- 0.48 mm respectively. Z value in coordinates of center of mass (X, Y & Z) attained peak value of 0.78 +/- 0.04 mm. The average volume of total corneal has resulted 23.60 +/- 2.28 mm^3.

The KC affected corneas having minor visual impact is analyzed for the thinning of corneal and identified that these thinning was displaced with referenced to vertex of the corneal due to its asymmetric response to pathology development. Consequently, one more study researched normal eyes geometric response and initial KC stages. As the study did not gather consistent thinning measures values in cornea of same geometrics, the inference were not sufficient enough. A new study indicated that, when we combine morphological analysis with eyes of KCs corneal thickness, disease pathogenesis involves both combinations. But, Mild Visual loss geometric profile and relationships which enables KC progression modeling have not been studied and analyzed with geometric models used here.

4. Morphological Analysis Using RNNs Classification

On the basis of curvature of anterior, refractive error and minimum corneal thickness, Severity of Keratoconus was graded. Maps that are analyzed in Computer generate 161 features per one eye which is randomly chosen per subject. Step-by step LDA referring to linear discriminant analysis and NN referring to neural network analysis had been conducted to develop models of multivariate on the basis of select features combinations with an appropriate order cases. The values like sensitivity, specificity and AUC (area region covered under the receiver operating characteristic curve) are identified for every classifier.

4.1 Stepwise Discriminant Function Analysis

Analyzing corneal response with the morphological analysis were performed along with geometric models to linear decomposition and singular points support hypothesis which mentions annular profile and explains focal weakening in KC development incipient stages. Accuracy of the results with KC's geometrical reconstruction having minor visual loss was specified clearly from displacement of posterior apex. Thinnest point deviations of anterior and posterior were significantly interrelated between minor keratoconic corneas in typical 3D model geometry that was attained by recently described approach. Discrimination model will be built stepwise in discriminant function analysis. Especially, at every step all variables are analyzed and evaluated to identify which one would mostly contribute to group's discrimination.

4.2 Analysis of Variance

With the statement, discriminant function problem can be other words called one-way analysis of variance problem (ANOVA). Especially, one would question if two or more groups are significantly different from one another with reference to the particular variable mean or not. In order for variable to have discriminates between the groups, learning more about statistical significance test of mean differences in the group and having significantly different mean in various groups are necessary. Above conditions will enable to say that these variables discriminate between the groups.

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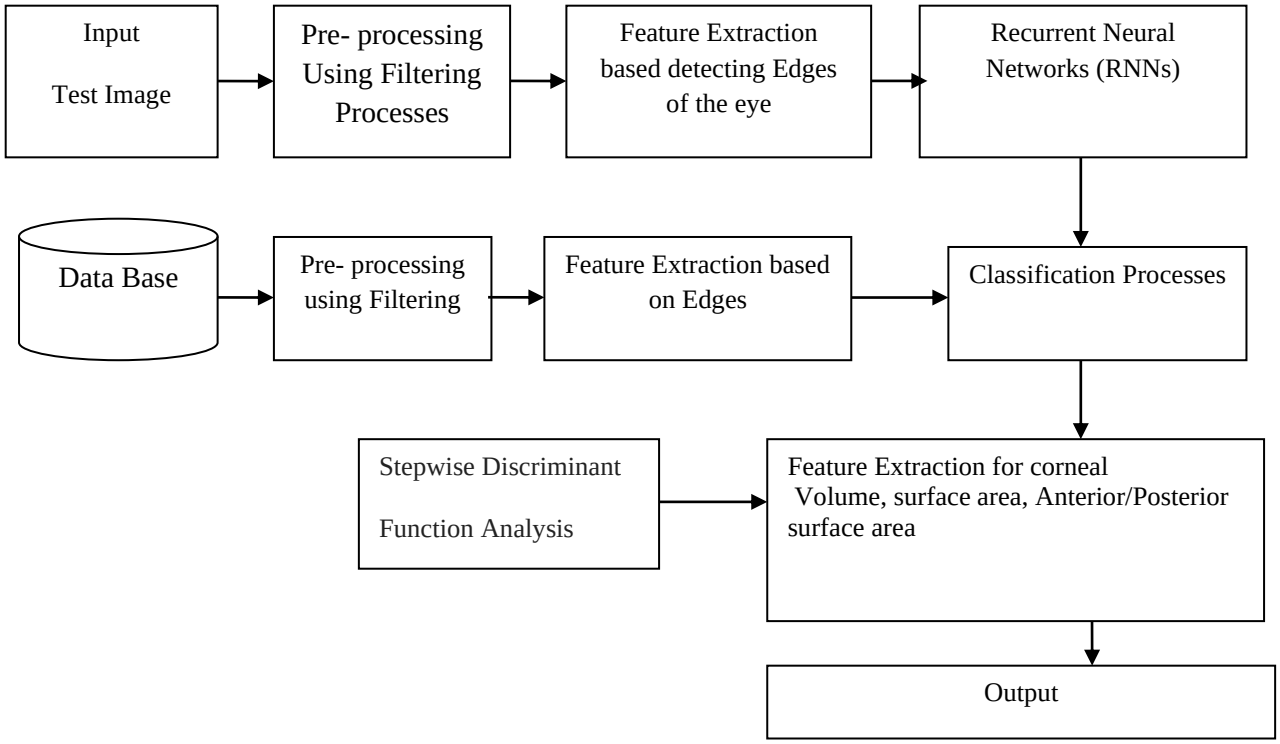

Fig. 4 Morphological Analysis Using RNNs Classification

Test data considered as input data, the noise are eliminated with the help of filtering processes which is on the basis of edge detection existing in the eye it occurs as characteristic of extraction processes. In conventional networks like neural method, it has an independent input and output variables to one another; however, in order to predict a sentence's next word, previous words are needed. Hence, it is necessary to remember the previous word. This is why RNN has come into existence that would solve this problem by Hidden Layer. Hidden state is most important characteristics of RNN that remembers some specific information of a sequence. Analysis of data base images is done by same processes. And based on classification, the posterior apex deviation mean value (0.19 +/- 0.10 mm) was more than apex deviation value of anterior (0.01 + /- 0.02 mm).

Two criteria are used by LDA to create a new axis:

1. Maximize the distance between means of the two classes.
2. Minimize the variation within each class.

Discriminant Function Analysis or Normal Discriminant Analysis or Linear Discriminant Analysis is a technique used to reduce dimensionality which is generally applied for the classification problems which is supervised. It is useful in modeling differences within groups i.e. segregation of two or more classes. It can be used to present the features into lower dimension space from higher dimension space.

4.3 Algorithm for Training through RNN

1. The network has the single time step for the input provided to the network.
2. The calculation needs its current state with the set of current input and previous state.
3. Next step the current stage ht changes ht-1 to the next time step.
4. The work undergoes the processing step and predicts the information and joint with the present state.
5. The time steps are processed to taken as the output.
6. The comparator process the targeted with the output and the error report is generated.
7. The error is then back-propagated to the network, order to update the weights and hence the network (RNN) is trained.

5. Result Analysis

The current work is simulated with the help of Matlab software and the result of image of input keratoconus undergoes preprocessing stage, contrast stretching process, etc., which are shown in below figure.

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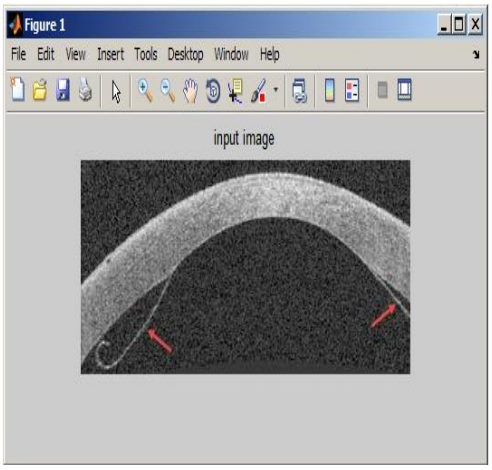

Fig. 5.1 Input Image

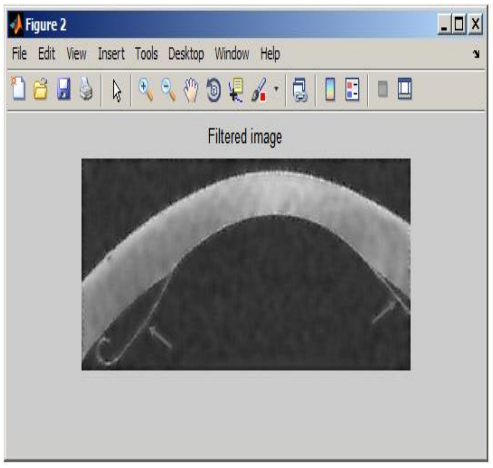

Fig. 5.2 Filtered Image

Image of input considered for the process is shown in Fig. 5.1. Filtered images after removing noise is shown in Fig. 5.2. The contrast stretched image with the help of contrast adjust function is stated in Fig. 5.3. Here is where the noise are reduced randomly.

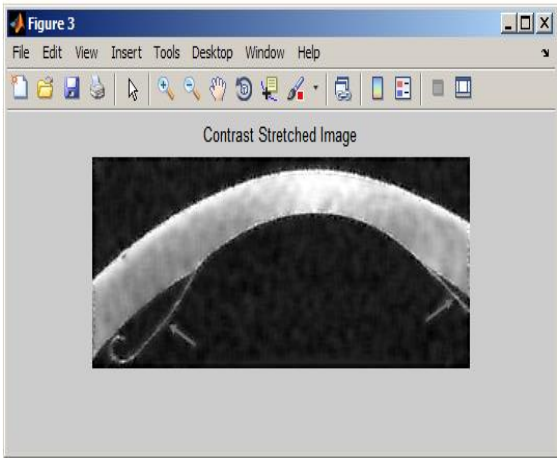

Fig. 5.3 Constrast Strtched function

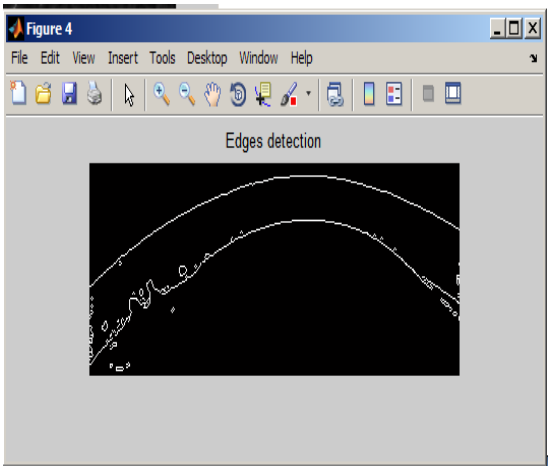

Fig. 5.4 Edge detection function

Input image applied with edge function with image processing edge function is shown in Fig. 5.4.

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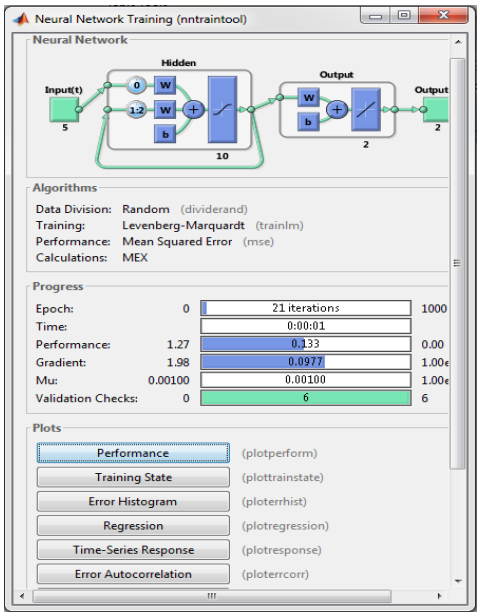

Fig. 5.5 RNN traning function

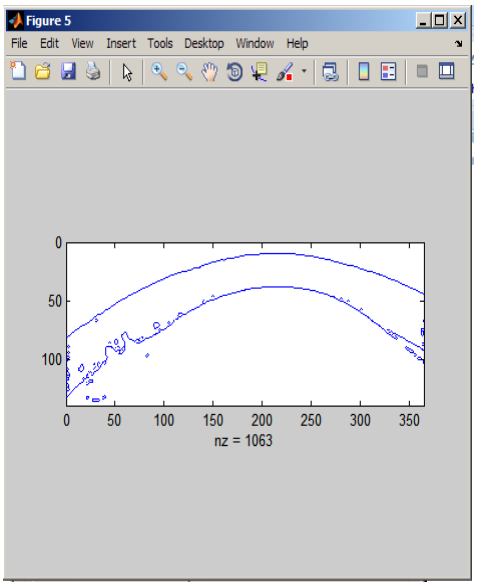

Fig. 5.6 Edge detection function

Using 1.5 neural networks in RNNs traning function is shown in Fig. 5.5. Edge detection function with basic details is shown in Fig. 5.6. Detection is performed for proposer edges with classification processes. Discriminative analysis function is performed in next steps by stepwise.

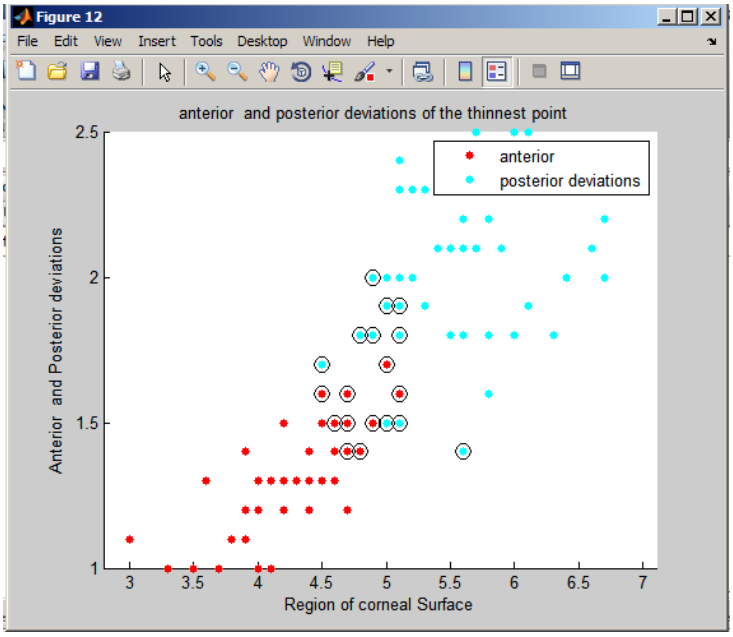

Fig. 5. 7 Anterior and posterior seperation using the thinesst points.

ROC analysis of posterior surface of apex deviation is shown in Fig.5.7. Highest coefficient of discriminant occurs as apex refers to corneal surface's maximum curvature point. Deviations of minimum thickness point of corneal surfaces are identified with significant differences between both groups.

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Table 2 Comparison of keratoconus eye for current and recommended work

S.No.	List of Parameter	Existing Range Values	Proposed Work Values
1.	corneal volume	4.391829e+01	4.391829e+01
2.	corneal thickness	2376	2376
3.	thinnest corneal thickness	135	135
4.	corneal Area	210	210
5.	corneal Perimeter	4.727280e+02	4.727280e+02
6.	The given input image	keratoconus eye	keratoconus eye
7.	Accuracy	76.66%	96.669%
8.	Sensitivity	6.571429e-01	4.9
9.	Specificity	0.05	0.1

Parameters of keratoconus eye of current and proposed systems are shown in Table 2. Parameter includes corneal thickness, corneal volume, thinnest corneal thickness, corneal area, test report and cornea perimeter, etc., It also shows parameters of performance like sensitivity, accuracy and specificity. The accuracy improves from 76.66% to 96.66%, the value of sensitivity reduced from 6.57 to 4.9 and also the increased specificity of 0.1 from 0.05. System's performance increases to 96.6%.

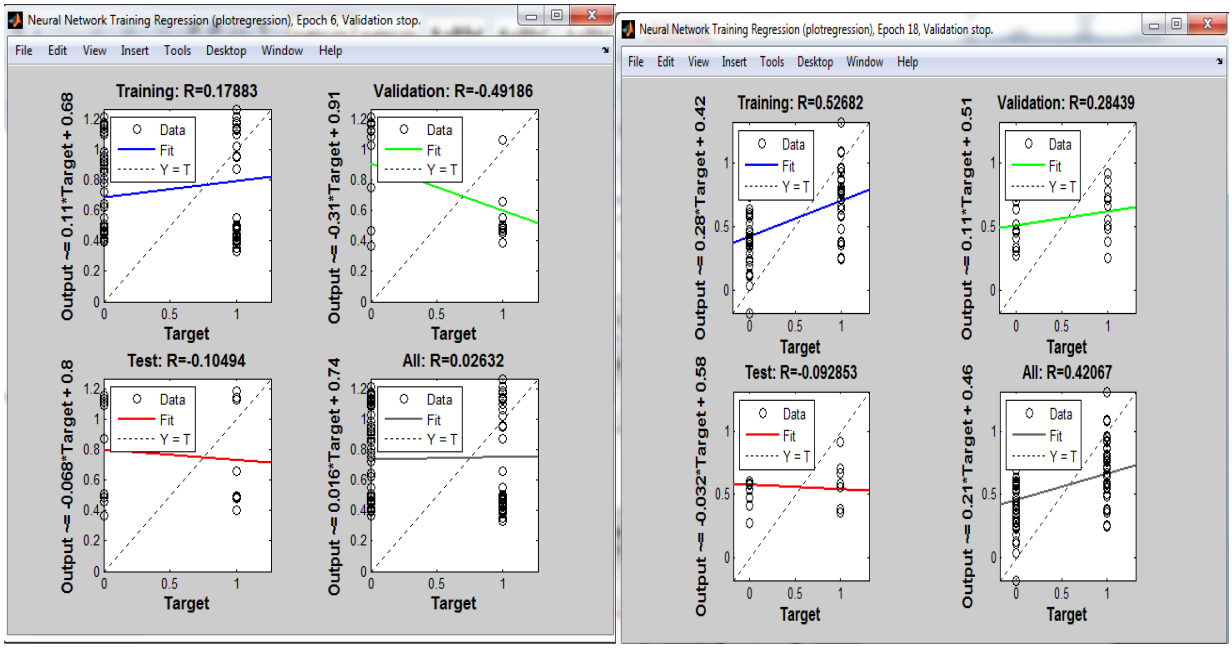

Fig. 5.8 Anterior and posterior seperation using the thinesst points.

Regression plot of most noteworthy relationships between the morpho-geometric variables of the group of keratoconus (n = 80) are shown in Fig.5.8.

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Table 3 Result Obtained

S.No.	Morpho-Geometric Variable	Acronym	Existing value	Proposed Value
1.	Corneal Volume(mm^3)	CV	0.969	0.97
2.	Anterior/Posterior corneal surface area (mm^2)	A_{ant} /A_{post}	0.853	0.84
3.	Corneal surface area (mm^2)	A_{tot}	0.699	0.7
4.	Posterior sagittal plane apex area (mm)	$D_{antapex}$/$D_{postapex}$	0.996	0.9
5.	Sagittal plane area at minimum thickness point (mm^2)	$A_{postmet}$	0.82	0.85
6.	Central of mass X,Y,Z (mm)	CMx/CMy/CMz	0.73	0.75

The Morpho-Geometric Variable of current and recommended systems are sown in Table 3. The variables obtained in proposed systems are close to the existing value. Also deviations of the anterior and posterior of thinnest point were significantly interrelated among minor KC in 3D model's specific geometry that was gathered with the help of newly explained approach.

6. Conclusion

The application of geometrical reconstruction of eyes of keratoconic corneas which is associated with minor loss of visual resulted in the accurate and most predictive results in displacement of posterior apex. The thinnest points of deviations in anterior and posterior were significantly associated within minor keratoconic corneas specified in typical 3D model geometry that was attained with newly described method. The suggested Morpho-geometric metrics provided noteworthy differences between the groups that might result in further enhancement of management of more tailored diseases which is based on the corneal visual impairment evaluation. The recommended frame utilized to identify the least thickness between surfaces of corneal with the help of Morpho-geometric Variables detection method utilizing RNNs networks provides more accurate result.

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