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A Linear SVM Approach for Detection of Keratoconus based on Morpho-Geometric Analysis

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Abstract: There are surfaces, indexes for refractive in terms of five and four different layer thickness over a human eye. A human's eye refractive state gets affected by any of the above parameters. By considering these parameters, the cornea would be the crucial parameter from the perspective of the refractive index. This paper intends to identify the asymmetry's structural characterization of the disease with the help of morpho-geometric parameters in keratoconus affected eyes along with a slight visual curb. This work also involves the application of patient-specific virtual model analysis using the Matlab R 2014 b application. Data are classified by Support Vector Machine by identifying the greatest hyperplane which splits all other data of one class from another class for decompensating of geometric or using modern methods and ideas. deformation of the curvature in corneal from a singular point defined by the apex of corneal. A regression of SVM inherited from deterioration such difference in which we declare an epsilon range from two sides of hyperplane to develop the function of regression insensible to the error not similar to SVM for differentiation in which boundary is defined to be safer to decide future.

Keywords: Thickness, Corneal surface, SVM, Anterior, Posterior

1. Introduction

Based on cornea analysis the same as a solid along by way of particular volume involving an assessment of relationships of various elements of the solid, modern geometric approach is derived that is a helpful tool for keratoconus detection. The application of combining various parameters on the basis of this geometric technique is huge sensitive approach and detailed to accurately detect initial keratoconus cases. The methods advancement to declare in vivo tailored cornea's geometric properties which are on the basis of actual raw data which is highly helpful to make a diagnosis and detect the diseases progression closely related to the architecture of corneal. The current work helps in improving the corneal ectasia prognostic generating a 3D cornea's tailored model and examining multiple geometric variables from the model to identify which variable or multiple variables combined can be defined as a susceptibility indicator to increase keratoconus [1]. Disease group (Non inflammatory corneal ecstasies include PMD (pellucid marginal degeneration), keratoconus (KC) and keratoglobus. Out of them KC is commonly found corneal ectasia form which is distinguished by progressive central thinning or low-grade cornea which causes steepening of corneal and formation of cone. The disease specifically displays during early 20s and is bilateral; however one eye is preceded by another one. It is been very challenging tasks to detect subclinical KC cases for refractive surgeons specifically when the indicative signs of clinical and differentiating of subclinical KC symptoms from the regular are not identified. Keratoconus is kind of disorder of an ecstatic corneal which is exemplified by progressive thinning of corneal thinning which would lead to protrusion of corneal, asymmetrical astigmatism and decrease in vision, especially the cornea presumes a shape of conical due to corneal stromal tissue's degeneration and the consequent biomechanical change [2]. Morphologic studies have disclosed huge no. of regular epithelial cells in

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periphery of the keratoconic while a cone's apex cells were expanded and organized in whorl-like model. A major pathologic problem in the KC cornea is considered with the disease which is linked to stroma apoptosis and probably the epithelium, resulting in corneal layers thinning [3].

All eyes established a complete ophthalmologic test which includes an analysis of anterior segment along with system of Sirius (CSO). Corneal curvature's Antero-posterior ratios (k ratio) and factor of shape (p ratio) were examined. Analysis of Logistic regression was utilized to assess whether some ratios of antero–posterior associated with another clinical factors were used to predict keratoconus existence. The earlier result is constant with present series' outcomes and it is also acknowledging the trend to most considerable steepening of posterior corneal when comparing with anterior corneal since keratoconus severity developed. Corneal power of both anterior and posterior was not typically evaluated per our earlier study. [4]. eventually, analysis of logistic regression was applied to detect specific independent predictors of the existence of keratoconus. A constant prediction model was found however shape factor ratios and the curvature of antero-posterior were not considered due to its limitation in capability of prediction. This is steady along with various other results of the present study which states for various parameters in k ratio of regular corneas and keratoconus corneas and a better variability level of factor ratio of the shape within individuals of group of keratoconus [5]. Following factors were analyzed; i) Best-fit sphere radii of the anterior and posterior, ii) Pachymetry of central corneal and thinnest corneal, iii) aconic shape parameters of anterior and posterior like aconic toricity, aconic asphericity and aconic radius and iv) anterior and posterior with elevation which is in the 1.0 mm in radius zone. A comparison of correlation connecting parameters of aconic shape between surfaces of anterior and posterior and elevation were done. A session 2 explains literature survey, the section 3 deals with a corneal morph geometric analysis model and section 4 specifies the algorithm applied for linear regression which is followed by conclusion.

2. Literature survey

Zuzana Schlegel et al., [6] recommended a regular group, high correlations were identified between the BFS radii of anterior and posterior, higher elevations and values of aconic radii; the relation between aconic asphericity of anterior and posterior and also values of toricity were feeble. The objective of this project was to examine and compare surface elevation topography characteristics of anterior and posterior in eyes of keratoconus-suspect with the help of an objective automated approach in detection on the basis of independent anterior specular topography data.

Fereshteh Aslani1 et al., [7] suggested the orientation of the axis of anterior corneal astigmatism, magnitudes, and posterior corneal astigmatism, ACA to PCA ratio, and the relation between PCA and ACA in the various phases KCN (keratoconus). The relation between astigmatism of corneal surfaces of anterior and posterior and mean keratometry in every four eyes group. Also, analysis of linear regression was done to identify the correlation between parameters of anterior and posterior and to detect specific relation with its parameters.

Faik Orucoglu et al., [8] stated that corneal surface parameters of anterior and posterior, indices of keratoconus, profile data of thickness and data from keratoconic developed elevation maps and regular cornea for the corneal tomography of Pentacam Scheimpflug and to identify the sensitiveness and peculiarity of the parameters to discriminate keratoconus from regular and general eyes. The Pentacam gives a corneal topographic multitude (keratometry), topometric, tomographic and data of Pachymetry. In order to get image with reflex free, lights in the room were turned off.

Mohammad Reza Jafarinasab et al., [9] recommended cornea elevation of posterior is noticed to improve the detection's sensitivity and peculiarity if applied with cornea anterior surface the measurements.

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Analysis of Cornea biomechanics and sensing of wave front disclosed the differences of general eyes and keratoconic eyes during its initial phase. Posterior corneal elevation contained high sensitivity and specificity to distinguish eyes affected by keratoconic from general eyes in initial phase of keratoconus than later on phases of keratoconus, with the basis of classification of Amsler–Krumeich keratoconus staging.

Yue Shi et al., [10] stated lesser to greater value, that is the cornea power difference between 5 inferior points average to average of 5 superior points and 3 mm distance with center of cornea with intervals of 30 degree created a NNM (neural network model) to identify and classification of abnormalities of corneal topography. Along with keratoconus, various abnormalities of cornea like post keratoplasty and post photo refractive keratectomy can be examined by this method. To generate a various factor system which clubs measurements of curvature, measurements of elevation, Pachymetry, biomechanics and cornea wave front error shall be trend in future to do a diagnosis of the keratoconus initial form which includes subclinical keratoconus and fruste keratoconus form.

3. Corneal Morpho-geometric Analysis

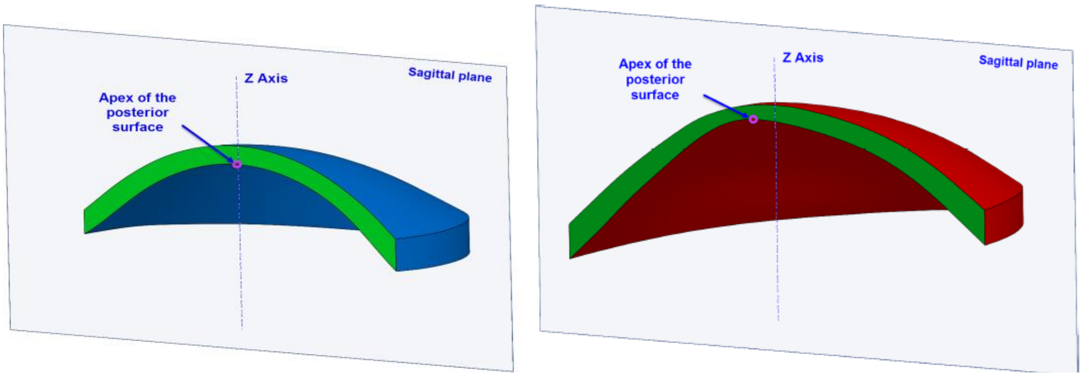

Figure 1: cornea area within the sagittal plane that passes through the Z axis and the posterior corneal surface's maximum point (apex) in a healthy eye (blue) and keratoconus cornea (red).

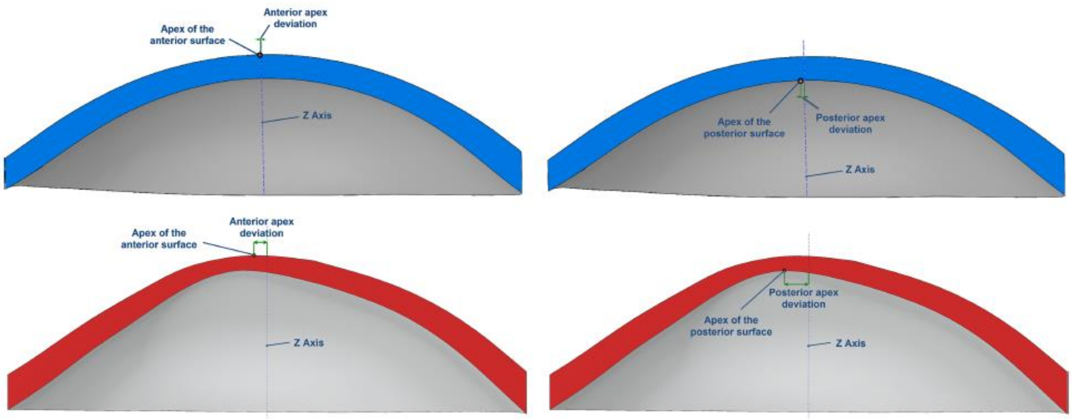

Figure 2: Cornea area within the sagittal plane that passes through the Z axis and the posterior corneal surface's maximum point (apex) in a healthy eye (blue) and keratoconus cornea (red).

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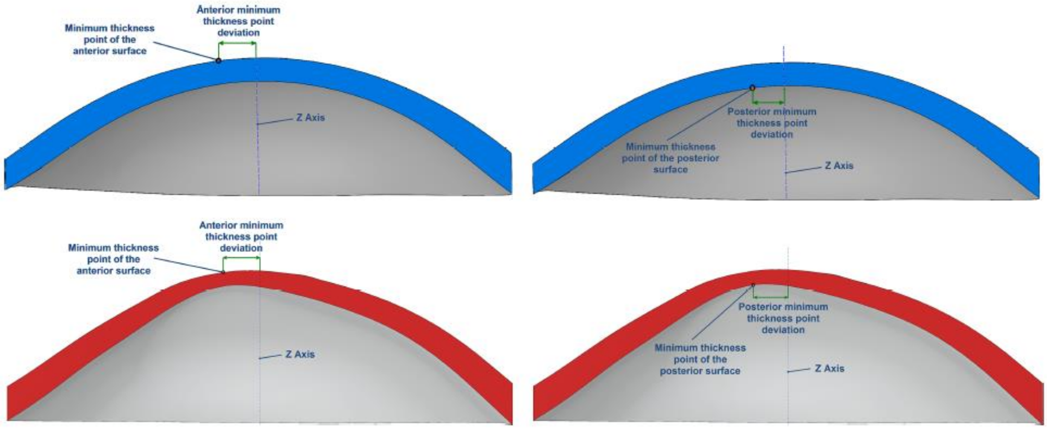

Figure 3. The average distance from the Z- axis into the anterior and posterior corneal surface with maximum point (apex) blue color for healthy eye and red color for keratoconus cornea.

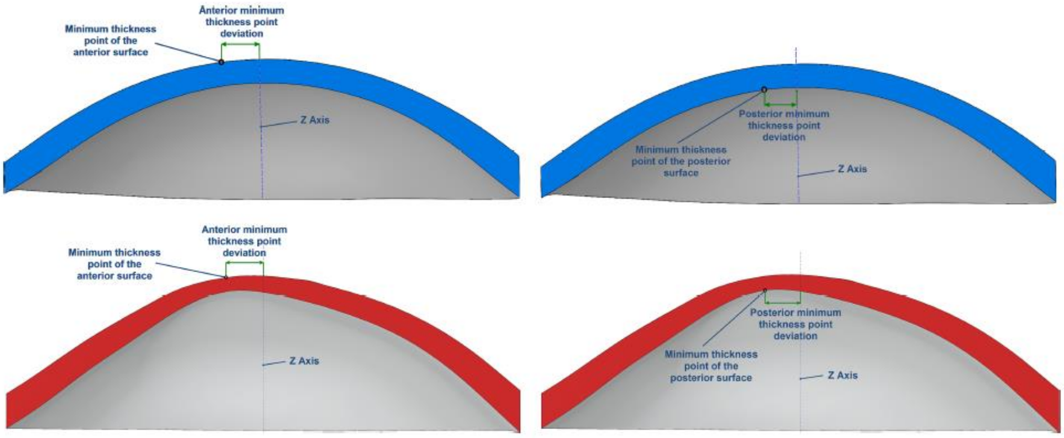

Figure 4. An averaging distance from the xy plane starts with minimum thickness point Z-axis with minimum thickness points (maximum curvature) healthy eye (blue) and keratoconus cornea (red).

3.1 Geometric modeling

A modeling of morpho-geometric be conducted with the steps defined earlier and our research has validated them.

The point cloud preparation

A geometry surface where point cloud is present was created in a system of coordinate for a space of three-dimensional. Programmed algorithm in MATLAB formatted the Topography files which were extracted in .csv format in Cartesian coordinates. Corneal map's circle is represented by each rows and semi-meridian is represented by each column and provides 256 points for every radius. Every i^{th} row which is sampled a map in the circle with radius of i_0.2 mm and which has the samples of mapping with the semi meridian in j_360/256u direction, hence every value Z for the matrix value [i, j] denoted the point P (i_0.2, j_360/256u) for the coordinates of polar. A cornea's center for geometric was found from a coordinates of XYZ given by the topographer who is corresponding to the Placido disc rings center. Especially, the point cloud is created for area which is as of the center of corneal geometric (r = 0 mm) with the starting of zone called peripheral zone (r = 4 mm). Area of analysis has better facts on corneal morphology for diseased and healthy eyes [11].

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The anterior and posterior areas for the model with solid of corneal surfaces created (Aant, Apost), indicates the total surface area of corneal (Atot), the cornea area within the sagittal plane that passes through surface of Z axis and the maximum point of surfaces of together corneals (Aapexant, Aapexpost), the cornea area within the sagittal plane that passes through Z axis and the least thickness point of surfaces of both corneal (Amctant, Amctpost), the average length from the Z axis to the maximum point of the surfaces of corneal of both anterior and posterior (Dapexant, Dapexpost) and the mean distance in the plane of XY from the Z axis to the least thickness points of the surfaces of the corneal of anterior and posterior (Dmctant, Dmctpost). The analysis of statistical contained descriptive statistics for groups of regular and KC to showcase the thirteen morpho-geometric variables distribution in detailed manner. The Kolmogorov-Smirnov test was used to check regularly. As possibility of analysis of parametric was in place, for data that are unpaired, the Student t-test was served as a comparison tool within groups. As condition reaches the normality stage, Student t-test related with the unpaired data, which focused on the measure up to groups. A Mann-Whitney test was applied for all other scenarios. It is decided to be major if p-value is less than 0.05 in all the tests. Parameters Correlation was examined by Pearson coefficients (for data that are normally distributed) or Spearman coefficients (other distribution). Keeping the objective of quantifying correlation strength within two groups, a linear regression was performed. ROC (handset in commission feature) curve were practical to identify total prognostic correctness for all the metrics with plotting graph of sensitivity versus 1-specifity [12].

The associated a sphericities are Q_x, Q_y respectively (asphericity is associated with eccentricity e by Q =-e2).

$$S = -19.2Q + 16.3R - 0.467 \quad \text{....(1)}$$

Where S is referred as surface area in square millimeters, Q is referring to asphericity and R is radius denoted in millimeters. Linear relationship of horizontal radius and surface area is indicated in the equation, stating a fixed sagittal height.

Posterior least thickness point deviation = 0.944 X Anterior least thickness
Point deviation + 0.236 (R2 = 0.997). … (2)

Sagittal plane area at least thickness point = 1.05 X Posterior_sagittal plane apex Area + 0.018 (R2 = 0.958)

Total volume of corneal = 5.757 X Posterior sagittal plane apex area + 1.197 (R2 = 0.953) ..(3)

Sagittal plane area at least thickness point = 0.16 X Total volume of corneal + 0.136 (R2 = 0.955)
Center of mass Z = 0.0195 X Total cornea surface area - 1.255 (R^2 = 0.907) …. (4)
Posterior sagittal plane apex area = 1.005 X Sagittal plane area at least thickness

Point - 0.031 (R^2 = 0.994) (5)

Total volume of corneal = 5.829 X Posterior sagittal plane apex area + 0.633 (R^2 = 0.978) (6)
Sagittal plane area at a least thickness point = 0.166 X Total corneal volume + 0.034
(R^2 = 0.978)…. (7)

A corneal response's morphological analysis using geometric models to decompensation which is linear and the annular profile for specified support of particular points the focal weakening hypothesis in phases of incipient in development of KC. Usage of KC eyes' geometrical reconstruction provides the best predictive accuracy KC eyes tested have mild loss of visual leading to apex displacement from the posterior. The deviations of anterior thinnest points and posterior of the thinnest point were relatively interrelated in the middle of slight keratoconic corneas in the typical 3D model geometry that was

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attained with the modern approach proposed. The recommended metrics of morpho-geometric provided remarkable differences within groups that might result in further development of a supplementary customized disease administration on basis of corneal illustration impairment evaluation [13].

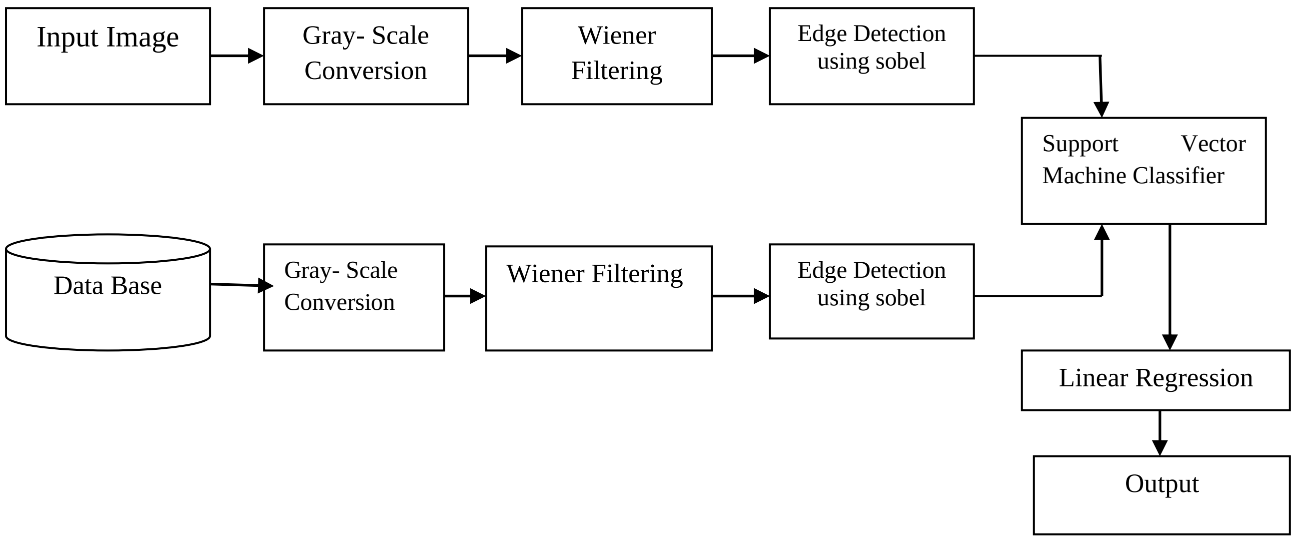

Figure 5: Detection of keratoconus with the help of Corneal Morpho-geometric Analysis

The figure 5 states detection of a keratoconus with the help of analysis of Corneal Morpho-geometric for the input image experiences the pre-processing phase like Wiener filtering, gray scale, detection of edge with sobel approach. SVM (support vector machine) classifiers compare the input data. The training data could experience the filtering processes and detection of edge processes. The training and trained images were created linear regression with the help of area of corneal and areas of corneal surfaces of the anterior and posterior.

3.2 Gray- Scale Conversions

The image with true colour RGB is converted to the input image with gray scale. The rgb2gray (map) is converted by the process of new map which is returning a greyscale colormap equivalent. If RGB image is input format, it could be with class of uint8, uint16, single or double. The image output I is the similar class as image input.

3.3 Wiener filtering

Restoration technique for de-convolution is the inverse filtering. That means when a known low pass filter blurs the image, it is feasible to improve the image with the help of inverse filtering process or inverse filtering with generalized. But, inverse filtering process would be highly sensitive to noise additive. The method of one degradation reduction at a time permits us to improve an algorithm of restoration for every degradation type and simply collect them. The Wiener filtering process accomplishes an optimal tradeoff in between noise smoothing and inverse filtering. It eliminates the noise of additive and reverts the blur in parallel. The Wiener filtering is ideal with reference to the error of mean square. It means that, it reduces the total mean square error in inverse filtering process and smoothing of noise. The Wiener filtering process is an estimation of linear with actual image. The technique is on the basis of a stochastic construction. A principle of orthogonally indicates the Wiener filter in domain of Fourier could exist denoted below:

$$W(f_1, f_2) = \frac{H^*(f_1, f_2) S_{xx}(f_1, f_2)}{|H(f_1, f_2)|^2 S_{xx}(f_1, f_2) + S_{\eta\eta}(f_1, f_2)}, \quad \ldots (8)$$

Where $S_{xx}(f_1, f_2)$, $S_{\eta\eta}(f_1, f_2)$ original image's power spectra and additive are noise respectively and $H(f_1, f_2)$ is the filter of blurring. It is easier to know that Wiener filter contains two different portions, part of an opposite filtering and division of a smoothing of noise. It achieves the de-convolution with process of filtering inverses (the filter with the specific characters of high pass) and also eliminates the noise along for an operation of compression filters with low pass characteristics [14].

3.4 Sobel filter

Edge detection is done by using the Sobel filter. It calculates the image intensity's gradient at image's every pixel. It identifies the direction of the maximum increase from lighter to darker and the change rate in this direction. To find a cell with the help of basic morphology and edge detection. If object contains enough contrast compared from background, the object could be detected without much effort.

These kernels are developed in such way to react maximally to all edges that are running horizontally and vertically related to the grid of pixel, one kernel per every two of the perpendicular directions. The kernels could be implemented individually to input image, to generate individual gradient component's measurements in every orientation (*Gx* and *Gy* are referring them). Gradient orientation and gradient's absolute magnitude can be found by combining these measurements. The gradient magnitude is calculated by below formula:

$$|G| = \sqrt{Gx^2 + Gy^2} \quad (9)$$

Especially, an approximate magnitude is calculated with:

$$|G| = |Gx| + |Gy| \quad (10)$$

This is a quicker way to calculate.

The edge's angle of orientation (in related to the pixel grid) gives rise to the spatial gradient is provided by:

$$\theta = \arctan(Gy/Gx) \quad (11)$$

In this scenario, orientation 0 is considered to average that the maximum contrast direction from black color to white color running from left side to right side on the image, and from this other angles are computed in anti-clockwise side[15].

3.5 Support Vector Machine (SVM)

A facilitate supervised machine learning algorithm is SVM (Support Vector Machine), which could be applied designed for together challenges in regression and classification. But, a widely applied in problems for classification. An algorithm has the facility for the every data plot indicates points in n-dimensional space with the number of feature point's value starts together specific coordinate values. A classification might be indicate the hyper plane that separates with two class with clear way.

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SVM Classifier Algorithm

1. The data points fit the fitcsvm model with the set of name values pairs arguments with Kernel Scale 'auto'. The training model for SVM termed SVM model. A software uses the heuristic procedure that select the kernel scale. Some heuristics features use the sub sampling. A set of random number uses the training before the classifier.

2. The cross validation for the classifier pass the cross-validation with the software conducts 10-folds cross validation.
3. The cross pass validation uses the SVM model with K- fold loss can eliminate and retain the retain the classification error.
4. The SVM classifier makes the 'Kernel Scale' and the ' Box Constrain' for the name value arguments pair.
5. The Box Constraints for a geometric sequence for the box constraints parameter.

6. Kernel Scale becomes strategy for the geometric sequence for the RBF sigma parameter that scaled for the kerenel original scale.

Recovering the actual kernel scale, e.g., ks, with the help of dot notation: ks = SVM Model. Kernel Parameters Scale. Using as factors kernel scales for original values. For example, multiplying ks indicates 11 values 1e-5 to 1e5, can increases with the factor for 10 model. Model which has least error of classification is chosen here. To get more accurate results, parameters need to be refined further. Process is started with Initial parameter and another cross validation step is performed with keeping 1.2 factor values.

4. Result Analysis

MATLAB application was used to implement framework of an input image which is gathered from database. Preprocessing and extraction of feature with the help of edge processes are performed. Classification of the features is done by the SVM and linear relationship with the help of regression.

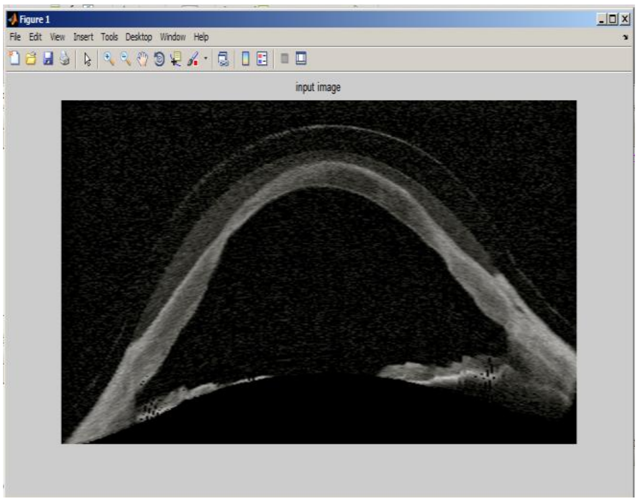

Figure 4.1 Input Image

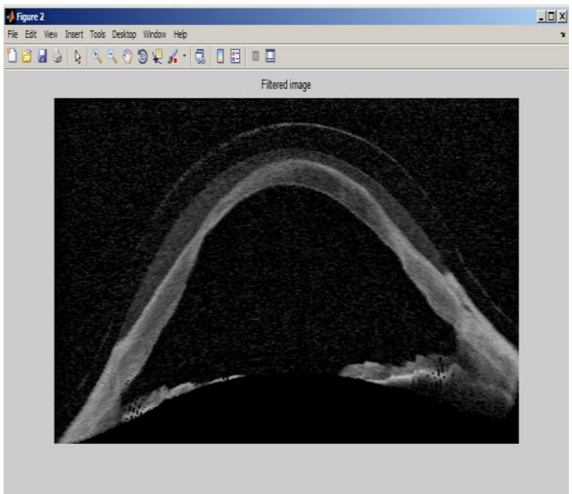

Figure 4.2 Filtered Image

Input image which is taken for analysis is filtered with the help of process called wiener filtering process which is shown in the figure 4.1

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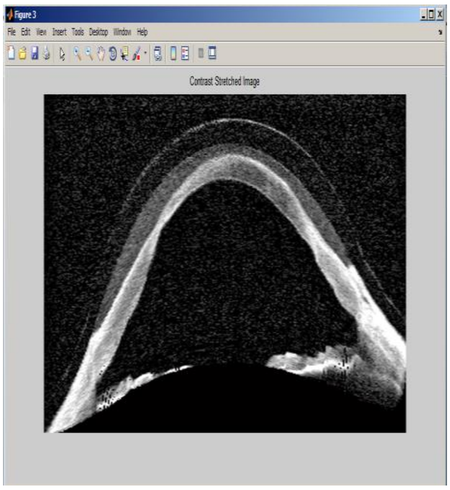

Figure 4.3 Contrast Stretched Image

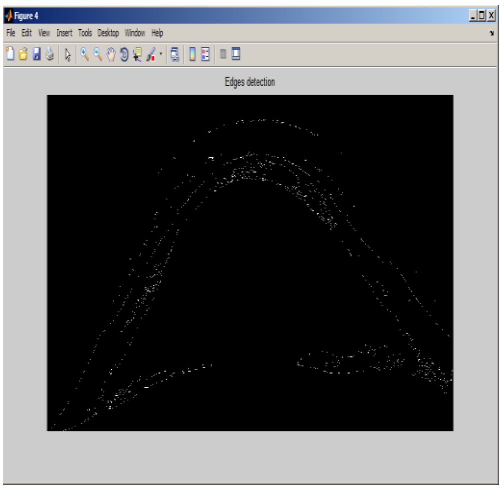

Figure 4.4 Edge Detection using sobel methods

Uneven process parts are processed by filtering processes, a contrast adjust is done with the help of image adjust function. Corneal maximum point and corneal areas of anterior and posterior of an image input is given.

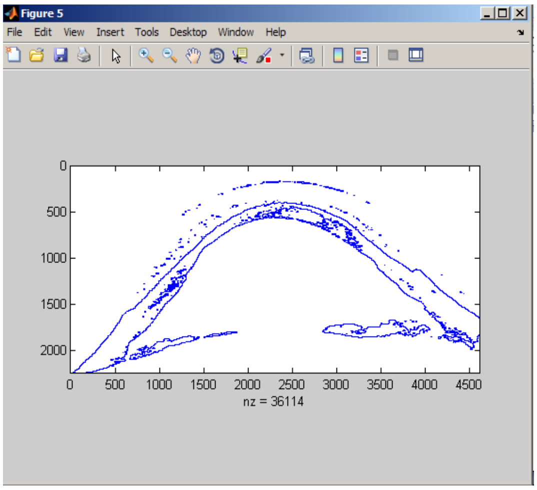

Figure 4.5 Corneal detection with edges

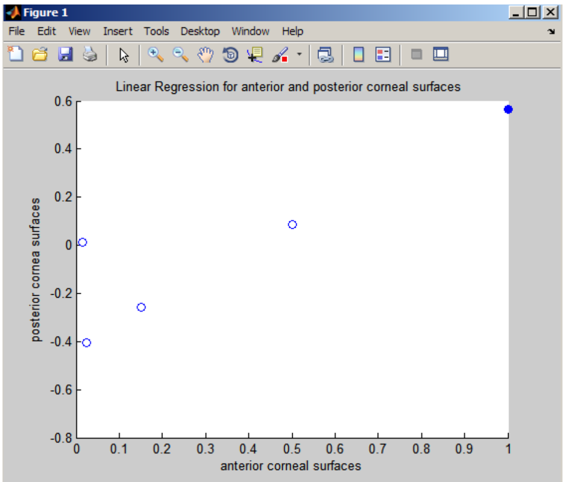

Figure 4.6 linear correlation between the variables.

Detection of Corneal with edge as an input image is shown in figure 4.5 and it is taken later analysis. The figure 4.6 gives the linear correlation of surfaces thickness of an anterior and posterior.

Table 1: Corneal Surface Parameter.

Sl.No.	Parameters	Values
1.	Apex of the anterior surface-mm	2.2360
2.	Apex of the posterior surface-mm	0.1600
3.	Anterior corneal surface area-mm	0.3760
4.	Post corneal corneal thickness-mm	0.5000
5.	Total corneal volume	43.9183
6.	Accuracy	90.00000e-01
7.	Sensitivity	60.00000e-01
8.	Specificity	1

Values received from apex's surface for anterior, posterior and corneal surface depth are shown in the table 1. Accuracy should be 90% in results in morphological analysis.

5. Conclusion

The recommended morpho-geometric metrics has shown crucial differences within groups that may result in further enlargement with more customized management of disease for the basis of corneal visual impairment evolution, which could also apparently be enhanced to another model of linear regression. This calculation tailor made method identifies the keratoconic modeling characterization profile in eyes having light visual impairment. This method creates the clinician along with a corneal architecture's three-dimensional view while slight visual loss occurs and it permits a consistent diagnosis of mild structure of the disease.

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