Detection of Keratoconus and Suspect Keratoconus by Machine Vision

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***Abstract*— Keratoconus is an eye disease that needs experts and topographical images of eye in its recognition. This paper focuses on developing artificial intelligence tool to diagnose Keratoconus. This tool can help manufactures in improving their devices to assist experts and improves the Keratoconus recognition phase either automatically or by expert. Our Artificial intelligence algorithm finds Keratoconus by employing features of topographical map of eye. These features are obtained by Pentacam and extracted by topographical images of eye via image processing techniques. We provide a dataset of the topographical images of eye by Pentacam in about six months and experts provide labels explaining if the images show sign of Keratoconus or they are suspect to keratoconus. This paper employs 82 topography maps of eye from dataset and classifies them into two categories: Normal (n=47) and Keratoconus (n=35). We use 12 features of each map as the input of a classifier. These classifiers are artificial Neural Network (NN) including Multi-Layer-Perceptron, RBFNN, Support Vector Machine, and Decision Tree. These classifiers are trained to detect Keratoconus or suspect to Keratoconus by part of dataset images and they are tested by the rest. The final result shows that we can detect Keratoconus, suspect to Keratoconus and normal eye by the proposed algorithm with about 91 percents accuracy.**

***Index Terms*— Keratoconus, Suspect keratoconus, Image Processing, Machine Vision, Neural Network, Medical Image Analysis, Topography corneal Pentacam**

Manuscript received on 15th of January 2012 and accepted on 26th of January 2012.
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I. Introduction

Keratoconus is a no inflammatory ecstatic dystrophy characterized by progressive thinning, steepening, and apicalconic protrusion of the cornea. These changes in corneal shape induce irregular astigmatism and myopic hift, causinggradual impairment of vision.[1,2]. Clinical diagnosis of moderate to advanced keratoconus is not difficult because of the presence of irregular astigmatism and the development of classic retinoscopic and biomicroscopic signs such as localized corneal thinning, Fleischer's corneal epithelial iron ring, Munson's sign,Rizzuti's sign, and Vogt's striae. However, the identification of subclinical forms of the disease in patients with normal best spectacle-corrected visual acuity and minimum or no clinical signs is challenging. [3].
Pentcam is a very compact analyzer capable to take Scheimpflug Images, 3D Analyzer of Anterior Chamber, Corneal Pachymetry, Corneal Topography, Cataract Analyzer and Real Corneal Aberrometry. With these all measurements, it is possible to obtain important observations and take maximum advantages of this technology. [4].

This paper focuses on how it is possible to diagnose keratoconus or suspect keratoconus automatically by the use of artificial intelligence. This will open the road to find proper solution to diagnose keratoconus in its early stage and provide room for more accurate treatment. We provided a dataset of topographical images of eye by Pentacam in six months in a laboratory and labeled them by eye specialists. We employed two sets of features as the inputs of recognition part of our system. These features are provided by analyzing images generated by Pentacam and the information obtained by Pentacam directly. Four groups of classifiers including Multi-Layer Perceptron (MLP) [5], RBFNN [6] Neural Network (NN), Support Vector Machine (SVM) [7] and Decision Tree (DT) [8] have been employed in the recognition phase of this paper. The simulations reveal the outputs of three classification schemes have approximately the same results. The rest of this paper is organized as follows. Next section describes the algorithm and talks about dataset gathering and the simulation results. Section III is on conclusion and future research.

II. The Proposed Algorithm

A. Review Stage

Our algorithm employs two sets of features. The first group is the features obtained directly by Pentacam and the second group is the features we obtained by analyzing the maps of topographical images acquired by Pentacam. Table I and Table II show the two sets of features.

At first we analyze the image of topographical map to extract appropriate feature to detect keratoconus. This involves image segmentation and feature extraction. These features are symmetry of Sagittal curvature, Randelman Score System [9], and Ambrosio Score System [10]. The Randelman Score is obtained by comparing the age of patient and her/his corneal thickness. The Ambrosio Score is obtained by comparing the prog-index and the least amount of cornea thickness. Both of these features are important for expert to diagnosis keratoconus.

The most difficult part is finding the symmetry of Sagittal curvature. This involves finding the symmetry respect to center of image and a line. The center of map is the center of the image matrix. The angle of this line respect to horizontal line of topographical image can be from 80 to 100 degree. These degrees are based on examining 120 images of dataset. A simple method in measuring symmetry is to find the symmetry of each point and the difference of image amplitude at those points respect to every line that has an angle between 80 to 100 degree, respect to horizontal line, and the center of image. The total absolute value of differences of all symmetrical points is a measure of symmetry. This value will be normalized by dividing it to a number constructed by multiplication of image sizes and the maximum image intensity. The normalized value will be between 0 and 1. More symmetry in image gives a number near zero. The reason is that, if two pixels are symmetrical to each other, then their difference and its normalized value will be near zero.

B. Data Collection

We spent 12 months in Vanak Eye Clinic in Tehran to gather topographical images of eye and labeled them by eye specialist. Pentacam device was used to obtain topographical images. We used 125 images as dataset. These images were divided into three groups of eyes; normal, suspect to keratoconus and keratoconus. Among these images, 47 these images, 47 images belong to normal eyes and 43 images belong to suspect to keratoconus and the rest belong to keratoconus.

C. Simulation Results

This paper employs four classifiers in recognition phase; SVM, MLP, DT and RBF. Weka is an open source software issued under the GNU General Public License.software15 version 3.6.1 was used to implement SVM , MLP, Decision Tree and RBFNN classifiers [12]. The inputs of all classifiers are the same. Table III shows the results when we compare two cases of normal eye and keratoconus. The results of all cases are approximately the same and in all cases we got the same result with the expert. Table IV shows the results when we compare all three groups of data. DT gives the best result. However, the results are more unsatisfactory when we compare two groups of data. DT as the best classifier gives 84% accuracy and BRFNN as the worth one gives 71.20% accuracy. Table V is similar to Table III, but it is the result of comparing suspect to keratoconus and keratoconus. The best result is 92.2 percents and the worth is 84.42 percents accuracy. The results presented in Table V are important and more difficult to measure in comparison with the results presented in Table 3. These results are suitable to decide about surgery. Table VI presets the results of comparing normal and suspect to keratoconus. The results are less satisfactory than the results of Table III and Table V. The reason is that the difference between the features of suspect to keratoconus and normal eye is low.

TABLE I
FEATURES OBTAINED BY PENTACAM [11]

NO	ATTRIBUTES	Description
1	Corneal Thickness	corneal thickness from the thinnest location to the periphery
2	Anterior best-fit sphere	Anterior using a floating alignment in a cornea fit zone of 9mm.
3	Posterior best-fit sphere	Posterior using a floating alignment in a cornea fit zone of 9mm .
4	Progression index	The progression index for the normative data is defined as 1.0.
5	Sagittal Curvature	The sagittal curvature is equivalent to the distance between the measuring point and the point where the perpendicular to the tangent at the measuring point intersects the axis.
6	Tangential Curvature	The tangential curvature is the curvature of the cornea at the measuring point. In the tangential presentation mode irregularities in corneal geometry appear more pronounced.
7	Relative Pachymetry	A reference map from these single maps is than calculated and normalized to the thinnest spot that has the value zero.
8	CTSP	Corneal Thickness Spatial Profile.
9	Age	Patient Aged

TABLE II.
FEATURES OBTAINED BY ANALYZING THE MAP OF TOPOGRAPHICAL IMAGE

	Attributes	Description
1	Randleman score system	Calculate Randleman score system
2	Ambrosio Score System	Calculate Ambrosio score system
3	Symmetry in map of Sagittal.	Detection Symmetry in map of sagittal by machine vision.

ISBN: 978-988-19251-1-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

III. CONCLUSIONS AND FURTHER RESEARCH

This paper presented the applications of AI algorithms in recognizing normal, suspect to keratoconus and keratoconus eyes. Data produced by Pentacam were gathered in one year from an eye clinic in Vanak Tehran and labeled by eye specialist. The simulation results were promising. It is possible to improve the accuracy if we add more features and employ feature selection algorithms. In all our simulations, there were no distinctions between features. If we can find the relevancy and redundancy of features, we can improve the accuracy and the simplicity of algorithms.

ACKNOWLEDGMENT

Authors would like to thank Ahmad Khajenezhad for his assistance, guidance and, for his valuable recommendations and suggestions, Maryam Aliakbarpour for providing special facilities to save time. Special thanks should be given to Vanak Eye Clinic and also Farinaz Mahmoodi and Mojgan Paknia who helped us to finish this work for the first time in I. R. Iran.

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TABLE III
RESULTS OF CLASSIFICATION OF NORMAL AND KERATOCONUS EYE

Classification	MLP	BRFNN	SVM	DT
Correctly Classified Instances	100%	100%	98.72%	100%
Incorrectly Classified Instances	0 %	0 %	1.28%	0%
Total Number of Instances	78	78	78	78

TABLE IV
RESULTS CLASSIFICATION OF ALL THREE GROUPS

Classification	MLP	BRFNN	SVM	DT
Correctly Classified Instances	77.60%	71.20%	72.00%	84%
Incorrectly Classified Instances	22.40%	28.80%	28.00%	16%
Total Number of Instances	125	125	125	125

TABLE V
RESULTS CLASSIFICATION OF SUSPECT TO KERATOCONUS AND KERATOCONUS

Classification	MLP	SVM	D T
Correctly Classified Instances	92.21%	84.42%	91%
Incorrectly Classified Instances	7.79%	15.58%	9%
Total Number of Instances	77	77	77

TABLE VI
RESULTS CLASSIFICATION OF NORMAL AND SUSPECT TO KERATOCONUS

Classification	MLP	SVM	DT
Correctly Classified Instances	79.78%	68.54%	83%
Incorrectly Classified Instances	20.22%	31.46%	17%
Total Number of Instances	89	89	89