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"DETECTION of KERATOCONUS USING IMAGE PROCESSING and MACHINE LEARNING"

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Abstract: Keratoconus (KTC) is a noninflammatory disorder characterized by progressive thinning, corneal deformation, and scarring of the cornea. The pathological mechanisms of this condition have been investigated for a long time. In recent years, this disease has come to the attention of many research centers because the number of people diagnosed with keratoconus is on the rise. In this context, solutions that facilitate both the diagnostic and treatment options are quickly needed. The main contribution of this work is the implementation of an algorithm that is able to determine whether an eye is affected or not by keratoconus. The Kerato Detect algorithm analyzes the corneal tomography of the eye using Image Processing which is able to extract and learn the features of a keratoconus eye. The Convolution Neural Network (CNN) is used for the classification of keratoconus eye and normal eye. The results show that the Kerato Detect algorithm ensures a high level of performance, obtaining an accuracy of 91.38% on the data set. Kerato Detect can assist the ophthalmologist in rapid screening of its patients, thus reducing diagnostic errors and facilitating treatment.

Keywords: Convolution Neural Network (CNN), Keratoconus (KTC) .

1. INTRODUCTION

The cornea is the outer layer of the eye, the surface covering the front of the eye. The structural and repair properties of the cornea are essential for its function such as protecting the inner contents of the eye, maintaining the shape of the eye, and achieving light refraction. The cornea is composed of proteins and cells and does not contain blood vessels unlike most tissues in the human body. The existence of blood vessels may affect its transparency, which in turn may affect the proper light refraction, hence worsening vision. Because there are no blood vessels that supply nutrients in the cornea, tears and an aqueous liquid provide nutrients to the cornea. Keratoconus is a noninflammatory condition characterized by progressive thinning, deformation, and scarring of the cornea. The pathological mechanisms of keratoconus have been investigated for a long time. Both the genetic and environmental factors have been associated with the disease, but in recent years, a new theory emerges that keratoconus could also have an inflammatory component.

At early stages the Symptoms of Keratoconus are similar to those any of Refractive Defect of eye so early detection of disease is hard. The figure shows difference between Normal eye and Keratoconus effected eye. Imbalance of enzymes with in Cornea results in Weakening of corneal tissues which leads to Keratoconus. This imbalance makes more susceptible causing Cornea weakening and bulge forward. The cone deformation reduces the visual accuracy. Optical coherence tomography (OCT) is being increasingly used as a tool in the diagnosis and management of keratoconus. Since its conception in the 1990s, optical coherence tomography (OCT) has become an important non-invasive, high resolution, imaging modality in the assessment of the cornea and anterior segment. Images and measurements of corneal thickness, and in particular, epithelial thickness, may be important in diagnosing early cases, and following procedures such as intrastromal corneal ring segments, corneal transplants and corneal collagen cross-linking.

3. LITERATURE SURVEY

1.Automated Detection and Measurement of Corneal Haze and Demarcation Line in Spectral-Domain Optical Coherence Tomography Images

This system proposes the first method that employs image analysis and machine learning to automatically detect and measure corneal haze and demarcation line presence and depth in OCT images. The automated method provides the user with haze statistics as well as visual annotation, reflecting the shape and location of the haze and demarcation line in the cornea. Our experimental results demonstrate the efficacy and effectiveness of the proposed techniques vis-a-vis manual measurements in a much faster, repeatable, and reproducible manner.

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2. A Novel Technique for Robust and Fast Segmentation of Corneal Layer Interfaces Based on Spectral-Domain Optical Coherence Tomography Imaging

A novel approach to segment corneal layer interfaces using optical coherence tomography images is presented. C Validation based on 20 B-scan images from 60 volumes shows that three-layer interfaces in each image can be segmented within 0.52 s with an average absolute layer interface error below 5.4 µm. Compared with an existing method, the system is able to yield significantly better or similar accuracy at a higher speed with inferior software environment. From the validation experiments based on images from normal human subjects, images with keratoconus and images with laser in situ keratomileusis flap, this showed that the proposed customized Hough transform for circles can represent the corneal layer interfaces more accurately. On the other hand, Kalman filtering can handle the heavy noise exhibited in the image, and can be adapted to shape variation in order to be closer to the real-layer interfaces.

3. Statistical Modelling of Optical Coherence Tomography Images by Asymmetric Normal Laplace Mixture Model

In this paper, a new statistical model is introduced for retinal layers in healthy OCT images. This model, namely asymmetric Normal Laplace (NL), fits well the advent of asymmetry and heavy tailed in intensity distribution of each layer. Besides, due to the layered structure of retina, a complete mixture model is addressed to model the whole layers together. It is proposed to evaluate the fitness criteria called Kull-back Leibler Divergence (KLD) and chi-square test along visual results. The results express the well performance of proposed model in fitness of data except for 6th and 7th layers. Using a complicated model, e.g. a mixture model with two components, seems to be appropriate for these layers. The mentioned process for train images can then be devised for a test image by employing the Expectation Maximization (EM) algorithm to estimate the values of parameters in mixture model.

4. Segmentation and Quantification for Angle-Closure Glaucoma Assessment in Anterior Segment OCT

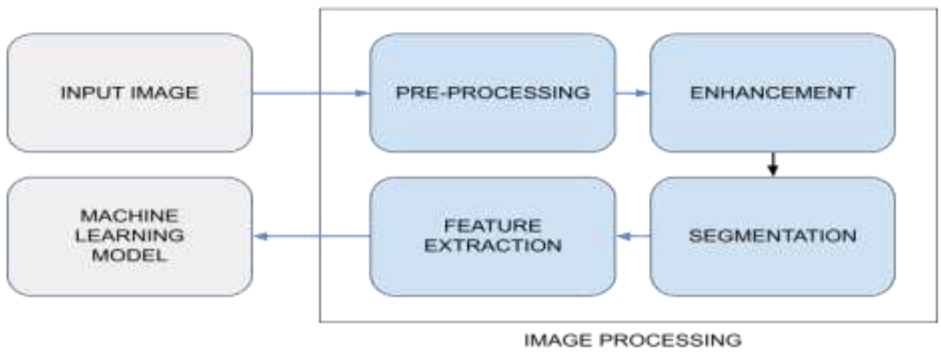
In this paper, a data driven approach is proposed for automatic AS-OCT structure segmentation, measurement and screening. This technique first estimates initial markers in the eye through label transfer from a hand labeled exemplar dataset, whose images are collected over different patients and AS-OCT modalities. These initial markers are then refined by using a graph-based smoothing method that is guided by AS-OCT structural information. These markers facilitate segmentation of major clinical structures, which are used to recover standard clinical parameters. These parameters can be used not only to support clinicians in making anatomical assessments, but also to serve as features for detecting anterior angle closure in automatic glaucoma screening algorithms. Experiments on Visante AS-OCT and Cirrus HDOCT datasets demonstrate the effectiveness of this approach.

5. Speckle Reduction in 3-D Optical Coherence Tomography of Retina by AScan Reconstruction

A new method for speckle reduction in 3-D OCT. The proposed method models each A-scan as the sum of underlying clean A-scan and noise. Based on the assumption that neighbouring A-scans are highly similar in the retina, the method reconstructs each A-scan from its neighbouring scans. In the method, the neighbouring A-scans are aligned/registered to the A-scan to be reconstructed and form a matrix together. Then low rank matrix completion using bilateral random projection is utilized to iteratively estimate the noise and recover the underlying clean A-scan. The proposed method is evaluated through the mean square error, peak signal to noise ratio and the mean structure similarity index using high quality line-scan images as reference. Experimental results show that the proposed method performs better than other methods. In addition, the subsequent retinal layer segmentation also shows that the proposed method makes the automatic retinal layer segmentation more accurate. The technology can be embedded into current OCT machines to enhance the image quality for visualization and subsequent analysis such as retinal layer segmentation.

4. METHOD

The primary steps involved in Image Processing are:



1. **Image Pre Processing**: Image pre-processing is an operation on images at the lowest level of abstraction whose aim is an improvement of the image data that suppress undesired distortions for further processing. The input images contain

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very low intensity values. Haze removal algorithm is employed here to remove the noise and to increase the intensity values. This step increases the visibility of the image.

2. **Image Enhancement**: Image Enhancement is the process of adjusting digital images so that the results are more suitable for future image analysis. In this model, we are employing Histogram Equalization Technique, sobel method to obtain image gradient. Gabor filter encodes edges while constructing the filter, orientation of the edges can be specified.

3. **Image Segmentation**: Image Segmentation is the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify the representation of an image into something that is more meaningful and easier to analyses. In this project, graph cut method is used to segment the cornea. The foreground cut is corneal layer, the background cut is the remaining part.

4. **Feature Extraction**: In image processing, feature extraction starts from an initial set of measured data and builds derived values intended to be informative and non-redundant, facilitating the subsequent learning and generalization steps, and leading to better interpretations. The required features such as cornea thickness, curvature are extracted from the image. These parameters are used to train the machine and classify the image data as affected or not.

5. SOFTWARE SPECIFICATION

5.1 OpenCV

OpenCV is a library of programming functions mainly aimed at real-time computer vision. It has a modular structure, which means that the package includes several shared or static libraries. We are using image processing module that includes linear and non-linear image filtering, geometrical image transformations (resize, affine and perspective warping, and generic table-based remapping), color space conversion, histograms, and so on. Our project includes libraries such as Viola-Jones or Haar classifier, LBPH (Lower Binary Pattern histogram) face recognizer, Histogram of oriented gradients (HOG).

5.2 OpenCV-Python

Python is a general-purpose programming language started by Guido van Rossum, which became very popular in short time mainly because of its simplicity and code readability. It enables the programmer to express his ideas in fewer lines of code without reducing any readability. Compared to other languages like C/C++, Python is slower. But another important feature of Python is that it can be easily extended with C/C++. This feature helps us to write computationally intensive codes in C/C++ and create a Python wrapper for it so that we can use these wrappers as Python modules. This gives us two advantages: first, our code is as fast as original C/C++ code (since it is the actual C++ code working in background) and second, it is very easy to code in Python.

6. SYSTEM DESIGN AND IMPLEMENTATION

6.1 Block Diagram

The below figure shows the block diagram of the detection algorithm. It is a representational of the whole project in brief.

In Neural Networks, the Convolution neural network is one of the main methods of recognizing and classifying images. CNN are currently used in applications such as object recognition and face detection. A CNN that is capable of diagnosing the keratoconus disease is implemented in this model.

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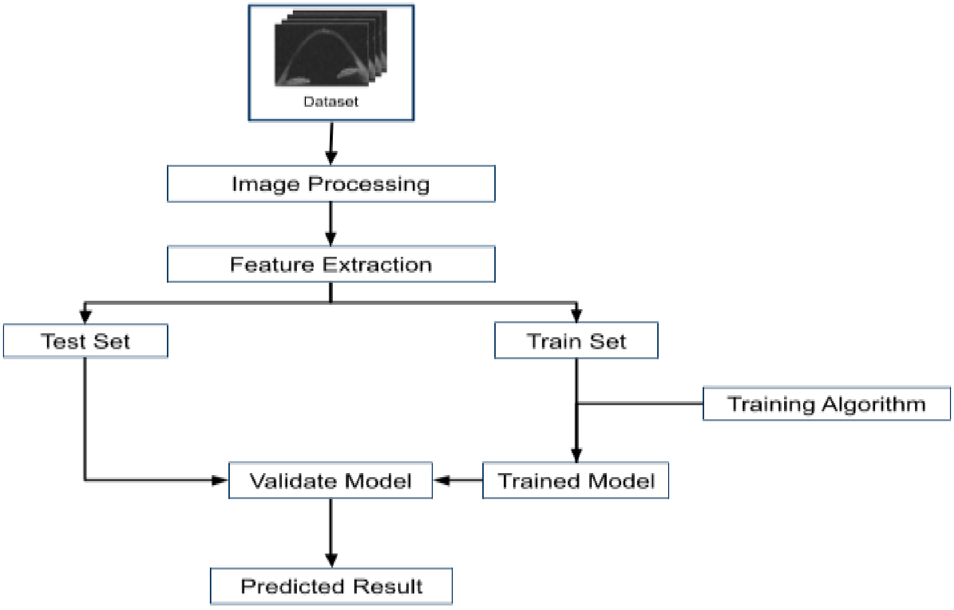
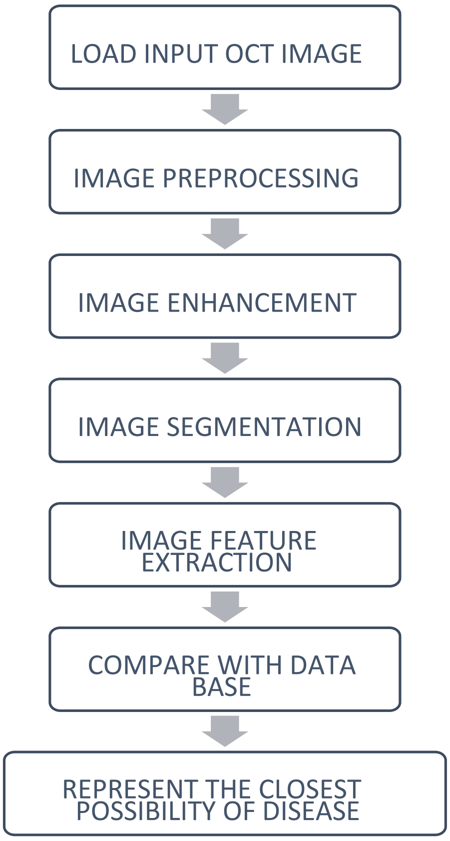


Fig : Block Diagram of Project

6.2 Sequence Diagram



6.3 Activity Diagram

The activity diagram is an UML diagram that describes the system's dynamic aspects. In fact, it is a flowchart that regulates the flow every event. The event can be described as the operation of the system. The control flow shall be taken between operations.

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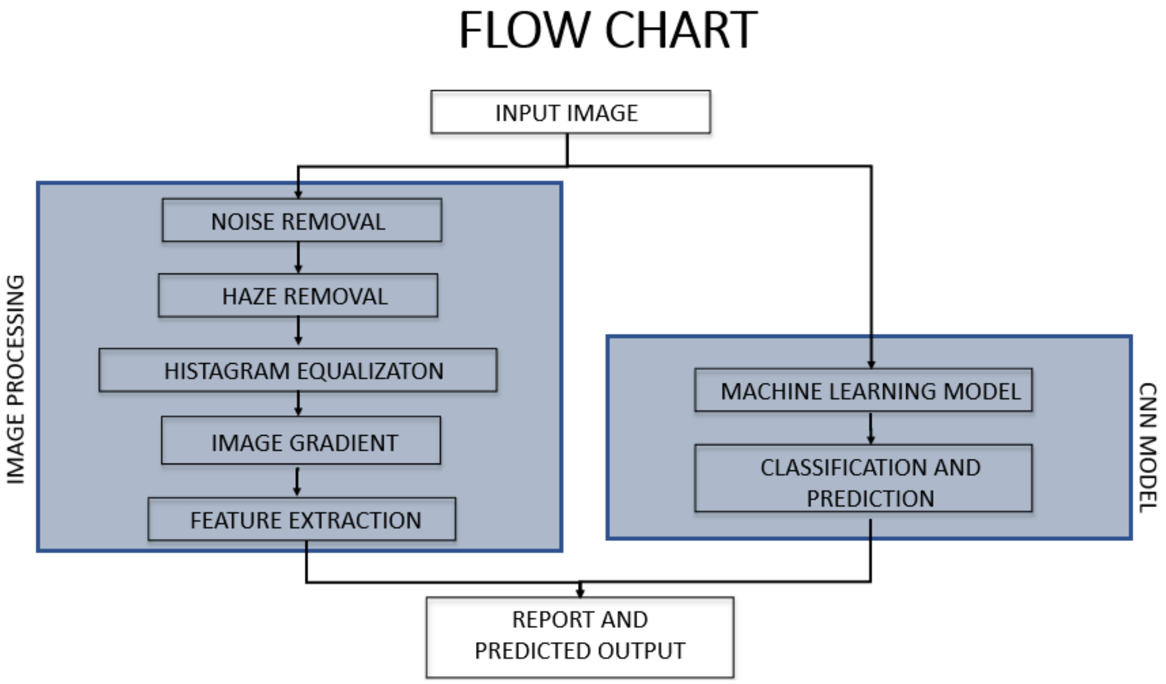
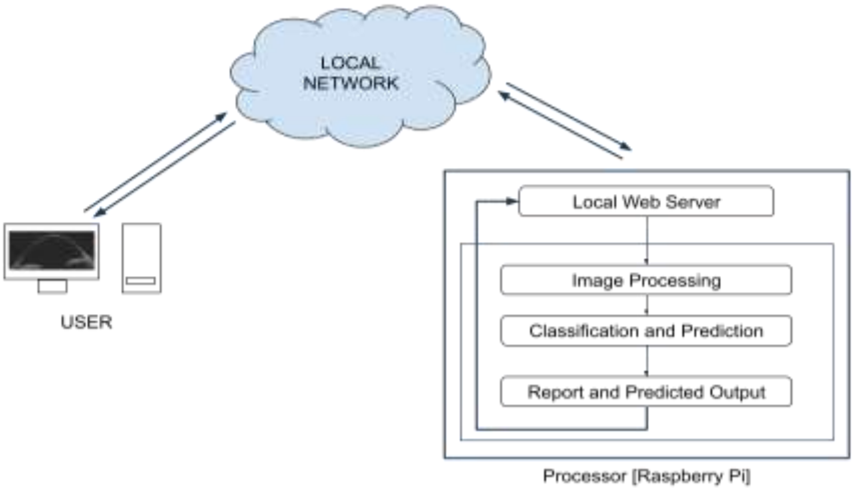


6.4 System Architecture



Input Image: The input image is taken from the pi camera which is connected to the Raspberry pi kit for the processing of the emotion recognition.
Image Pre-processing: Image pre-processing includes the removal of noise and normalization against the variation of pixel position or brightness.
• Haze Removal
• Dark Channel Prior
Image Enhancement: Image enhancement is the process of adjusting digital images so that the results are more suitable for display or further image analysis
• Histogram Equalization
Image Gradient or Color Progression: An image gradient is a directional change in the intensity or color in an image. The gradient of the image is one of the fundamental building blocks in image processing.
• Edge Detection
• Sobel Filter
• Gabor Filters

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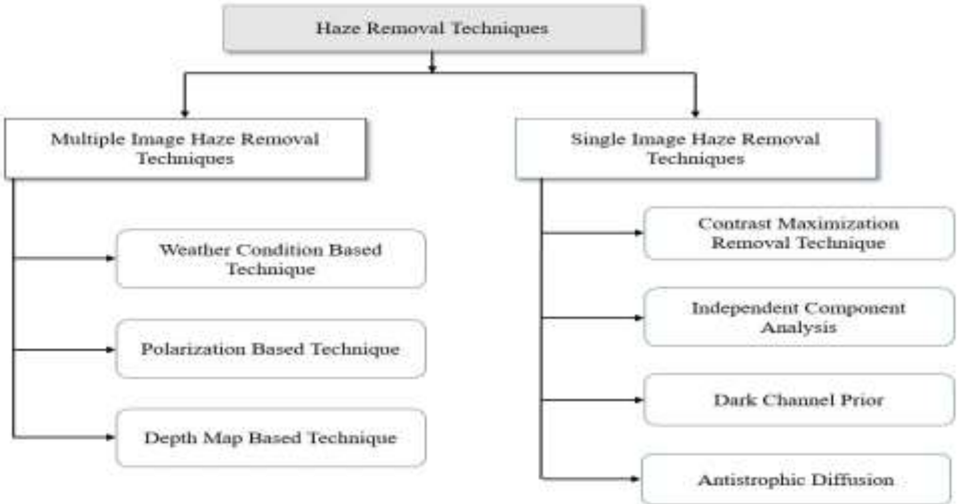
Image Segmentation*:* It is common to only be interested in a certain region of an image therefore segmentation techniques may be employed.

- Graph Cut Method

7. ALGORITHMS

1 Haze Removal

Haze (or fog, mist, haze and other atmospheric phenomena) is a main degradation of outdoor images, weakening both colors and contrasts. Haze is naturally an atmospheric effect. And it is the combination of air light and attenuation process. Air light increases the whiteness of the image and attenuation effect reduces the contrast. When increasing the distance from the image the clarity of the image automatically reduces. In order to increase the clarity of the image we perform the Haze removal or dehazing techniques. Haze and fog are an atmospheric effect, but they are different: fog is thick and opaque effect while haze is thin and translucent effect.



2 Histogram Equalization

Histogram processing is the act of altering an image by modifying its histogram.

Steps involved in Histogram Equalization Algorithm are as follows:

1. Create the histogram for the input gray scale image.
2. Calculate the cumulative distribution histogram.
3. Calculate the new gray-level values through the general histogram equalization formula.
4. The general histogram equalization formula (a mapping function) is:

$$l_{new} = \left[\left(\frac{cdf(l) - cdf_{min}}{(N \ x \ M) - cdf_{min}}(L-1)\right)\right]$$

Where,

$$cdf(l) =_{i=0}^{l} \in n_l$$

Fig : Before Histogram Equalization

Fig : After Histogram Equalization

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3 Sobel Filter

The Sobel Method calculates the gradient for each pixel within an image in order to determine boundaries within an image.

Formulation

- If we define **A** as the source image, $\mathbf{G}_x$ and $\mathbf{G}_y$ are two images which at each point contain the vertical and horizontal derivative approximations respectively.
- The computations are as follows:
- For a sobel filter to find the directional gradients in 2D images the weights are given as,

$$\mathbf{G}_x = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} * \mathbf{A} \quad \text{and} \quad \mathbf{G}_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * \mathbf{A}$$

Where, Gx and Gy are the directional Gradients in x and y direction.

- Since the Sobel kernels can be decomposed as the products of an averaging and a differentiation kernel, they compute the gradient with smoothing.

$$\mathbf{G}_x = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} * \left(\begin{bmatrix} +1 & 0 & -1 \end{bmatrix} * \mathbf{A} \right) \quad \text{and} \quad \mathbf{G}_y = \begin{bmatrix} +1 \\ 0 \\ -1 \end{bmatrix} * \left(\begin{bmatrix} 1 & 2 & 1 \end{bmatrix} * \mathbf{A} \right)$$

- Magnitude is given as :

$$\mathbf{G} = \sqrt{{\mathbf{G}_x}^2 + {\mathbf{G}_y}^2}$$

- Gradient Calculation is given as:

$$\mathbf{\Theta} = \operatorname{atan}\left(\frac{\mathbf{G}_y}{\mathbf{G}_x} \right)$$

4 Graph cut method

The user is able to draw a polygon around the region of interest to highlight the foreground and the image is then iteratively segmented. The graph cut method was extended by using an iterative process to segment foreground regions from the background, simplify the process of segmentation with minimal user engagement, also utilizing the use of border matting for estimation of alpha matte around an object's boundary.

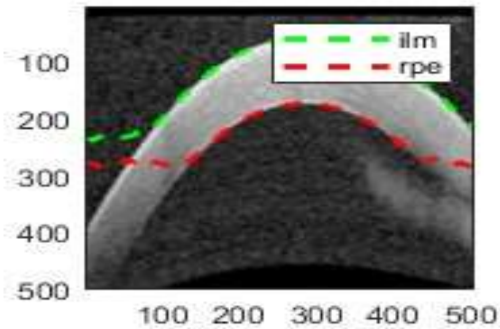

Fig : Image after Graph cut method

5 CNN

A convolutional neural network has attracted great attention in the field of complex tasks, mainly in image recognition. They were specifically designed to handle images as inputs, as they act in local receptive fields performing a convolution process. However, understanding the working principle of convolutional neural networks may not be an easy task, especially for beginners in the area of computational intelligence. The popularity of CNNs has increased dramatically with them being used by researchers to tackle a broad range of image and voice recognition problems. The use of pertained implementations of CNNs gives the potential for applying them to a variety of problem areas without having to train a CNN from scratch.

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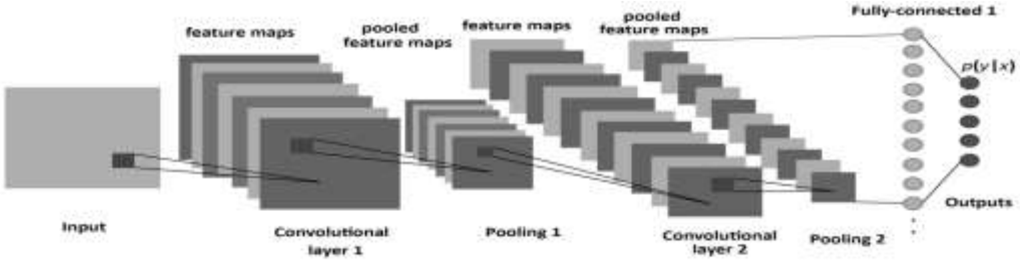


8. RESULT and FUTURE WORK

In this project, a new automated solution is performed that employs customized image processing and machine learning methods to detect and measure corneal thickness in OCT images for the detection of the keratoconus disorder. The experimental results highlighted the effectiveness and efficiency of the automated solution, which enables ophthalmologists to obtain fast, accurate and objective information on corneal haze. The proposed solution has the promise to be employed as standardized method of care for keratoconus detection of individual patients or in aggregate data for the purpose of longitudinal studies and may improve clinical decision making after corneal surgeries such as cross-linking.

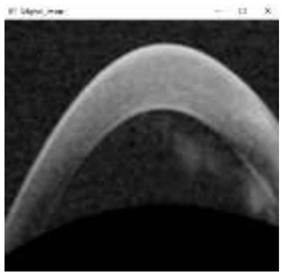


Fig:Original image

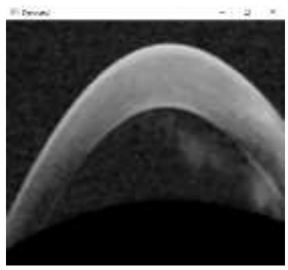


Fig:Pre processed image

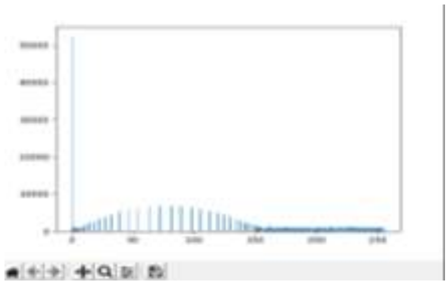
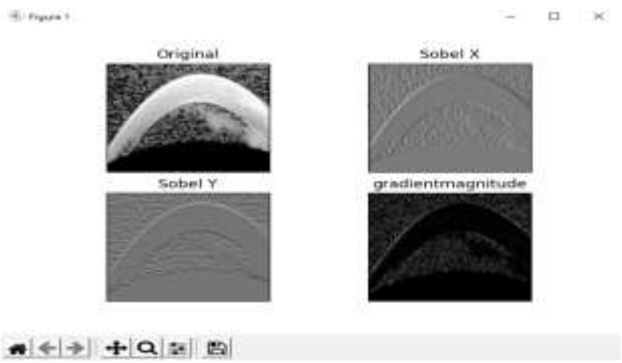


Fig: Histogram equalized image



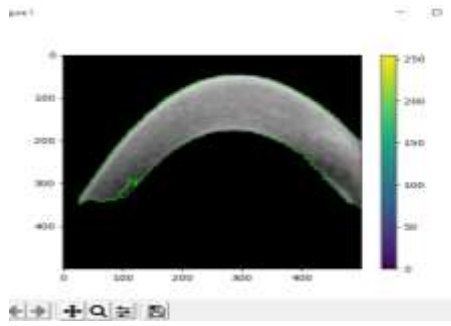


Fig:Image gradient using sobel method

Fig:Feature Extraction

Fig:Segmentation using grab cut method

As future work, it is possible to extend the automated tool to support most recent OCT machines, which also generate OCT scans of the cornea. More notably, automated analysis will have an even more important role in newer, upcoming OCT technologies, like the polarizationsensitive OCT (ps-OCT). Furthermore, since the corneal depth exhibits a small variation across time, to amend the algorithm's selection criteria such that it takes into consideration n sets of suggested/candidate cornea images at n different periods, so as to pick the most probable combination of lines can also be updated. Finally, this work can be modified to model the OCT images in 3D, which will provide a holistic view of corneal thickness and indicates bulged part, and thus may enable optimal evaluation of their presence and depth.

9. TRAINING AND VALIDATION PROCESS

The training data set is used to construct a predictive relationship for all machine learning models. In order to avoid over fitting it is necessary to have a validation set in addition to the training and test sets. The validation set is used to compare their performances and decide to select a model among different model. Validation set is used for determining the parameters of the model. We have designed a CNN algorithm in such a way that the images in the database are automatically divided for training,testing and validation. Maximum epochs given is 50.There were 3 iterations per each

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epoch.To avoid overfitting,iterations were stopped at 35th epoch only for this dataset. Validation frequency is 5 iterations.Validation criterion is met. Accuracy obtained for the model created is 91.38%.

10. CONCLUSION

The main advantage of the proposed algorithm is that it can be used as an integrated part of the diagnostic process. From the obtained results, we can conclude that the proposed Keratoconus Detection algorithm ensures a high level of performance. The main contribution of this work is the development and integration in the diagnostic process of an assistant software to help the ophthalmologist. Machine learning algorithms have the potential to interrupt classical medical screening programs, being able to provide diagnostics in a very short time as well as helping to increase patient care and comfort. The contribution of this project consists in applying a machine learning mechanism to keratoconus disease detection. The high level of performance can come to help the medical staff in correctly diagnosing keratoconus. Thus, after the ophthalmological consultation, the corneal tomography is applied as an input to the already trained neural network, and this will determine whether the patient is suffering from keratoconus or not. By optimizing the parameters associated with the convolutional neural network, the accuracy of the proposed algorithm was increased for the test set. The implemented algorithm processes optical coherence tomographies and classifies them into two categories, detecting patterns specific to the keratoconus pathology. In conclusion, this work presents the development of a screening tool based on a learning algorithm that automatically detects the keratoconus disease based on corneal tomographies. The algorithm can be implemented in the device that performs the tomography as an add-on in order to assist the ophthalmologist in rapid screening of its patients. Although the results show a high level of performance, this mechanism cannot be used as a stand-alone diagnosis procedure but should be seen as an additional tool to help the ophthalmologist who also analyzes other clinical data such as family history, refraction, and corneal shape evolution, and performs lamp examination. In the future, these algorithms will become more efficient and contribute to easy diagnosis of keratoconus and the reduction of corneal transplant cases.

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