Review article

Retinal analysis from OCT images to identify fluid filled abnormalities

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ABSTRACT

Blindness, being one of the most common disabilities in humans, is often caused due to various infections in the anterior and posterior regions of the Human eye. One of the common reasons include a significant variation in the levels of fluid in the retina of the eye. This may be due to excessive fluids or due to reduction in the levels of fluids. This paper reviews various tools of assessment designed towards early detection and diagnosis of such fluid filled abnormalities. The proposed idea has evaluated the various methodologies that have been designed and implemented using Image processing techniques, beginning from the preprocessing to classification at different stages. Not only focusing on binary classification, say normal and abnormal, various other techniques to classify the input image as Choroidal NeoVascular Membrane (CNVM), Cystoid Macular Edema (CME), Macular Hole (MH) and normal images has also been validated. Validation of the implemented speckle noise removal preprocessing filters and classifiers for efficient classification has also been focused on the paper.

Keywords: Optical coherence tomography; fundus Imaging; classifiers; medical image processing.

INTRODUCTION

Artificial intelligence and recognition systems have trended to be one of the most emerging that are in the field of medicine. Not restricting to therapeutic applications, the field of artificial intelligence has also significantly contributed to the diagnostic applications in the healthcare industry. Among such trending applications of artificial intelligence in medicine, a significant revolution in the field of ophthalmology. Few devices which have integrated such artificial intelligence systems for decision making and interpretation include the fundus camera and the optical coherence tomography devices. These devices are primarily used to capture the images of retina to obtain a clear picture of the fluid levels and vascularization pattern of the retina. This retinal region could be understood as the detector region, which is made of photosensors, namely, the rods and the cones which are responsible for night vision and color vision respectively. If the fluid levels in this region suffer variations, then this phenomenon may trigger visual impairment by various conditions. The variations in the levels of fluid either signify an increase or a decrease in the levels of retinal fluids. The excess of fluid may lead to a condition referred to as cystoid macular edema and the reduction may lead to a notable degeneration in the macular region of retina and is referred to as macular hole. If the fluid becomes in excess due to new vascularization in the retinal layer, then it is termed as choroidal neo vascular membrane. When a person is affected by these disorders, the way the patient perceives an image tends to vary, thereby disturbing the visual perception of the patient.

To diagnose these disorders commonly we use a device termed as Optical coherence Tomography (OCT; 1), which implements ultrasound source to image the retinal layers (2). Using this device various disorders including macular hole, macular pucker, cystoid macular edema, age related macular degeneration, glaucoma, central serous retinopathy, diabetic retinopathy, vitreous traction may all be detected. As a part of emerging digitization and implementation of PACs system throughout, digitally storable images with possible prediction/ interpretation have also become mandatory. The OCT images may have several shortfalls like speckle noises in acquired images, undesired variations of intensities, optical shadows, low optical contrasts, and irregularities in the anatomical structures. To overcome these shortfalls and integrate an artificial intelligence/ machine learning based decision-making system, this article reviews various methodologies used to solve the proposed problems. Earlier works in the field of ophthalmology in the domain of OCT images have extensively contributed segmentation of analysis of the intraretinal layers (3-12), identification of fluid filled layers (13,14) and segmentation of optical circles. As the OCT device utilizes ultrasound waves to obtain clear view of various layers of retina (15), using images of this modality shall be more appropriate to perform the analysis of various fluid-based abnormalities in the retina.

MATERIALS AND METHODS

The generalized methodology of an artificial intelligence-based decision-making system has been represented in fig. 1.

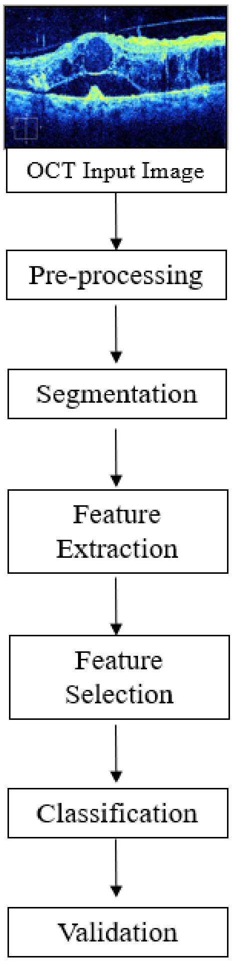

Fig. 1: Methodology

The digital images acquired using the optical coherence tomography devices are provided as input to the above detailed system. Further the noise removal is done after the grayscale conversion by appropriate methodology of preprocessing. As ultrasound remains the primary source for imaging of the retinal layers, the output image is more susceptible to the speckle noises, which are multiplicative in nature (16-18). To overcome this problem of speckle noises most commonly homomorphic filters are being used due to their nature by which the multiplicative components are made additive and then subtracted. This method of preprocessing has been found to be efficient by various related works. Following any of the preprocessing noise removal technique, by which the speckle noises are being significantly reduced, further segmentation of the image (19-21) is being done to highlight and enhance the essential region which is filled with fluids or to highlight and enhance the structural deformity that has been caused due to deficit of fluids. The excess of fluids not only refers to the ophthalmic fluids, say the vitreous humor but also the increased levels of blood that could be caused due to hemorrhages and neovascularization in various layers of the retina.

After segmenting the region/layer of interest various features are being extracted to obtain a clear idea of the details involved within the retinal layers that had led to such abnormalities that had occurred due to variations in the normal levels of fluids. The features are chosen in such a way that the structural differences and the textures are being clearly highlighted and extracted for further analysis of the systems. Most of the systems proposed have reduced, in other words, optimized the number of features used for further classification of the retinal images. This procedure of feature selection is vital to decide the further efficiency of the classifier. If the features are properly extracted and selected then the overall statistical evaluation parameters, say, accuracy, true negative, false positive, true positive and false negative (22) could be satisfactory for real time implementation of the developed system. In general, among the overall database, the dataset is being separated for Training and testing. Among the available dataset 70% of the images are taken for training of the developed algorithm and the remaining 30% of the images are used for testing and validating the developed algorithm.

DISCUSSION

Among the existing works (23-32), the evaluation of real time Optical Coherence Tomography image processing was done for 114 images that were obtained from Topcon and Zeiss brand OCT machines. Among those datasets 27 images were normal and 87 images were abnormal. Among this dataset 70% were used for training the developed algorithm and 30% were used for testing and validation. The sample image used for input, the gray scale transformed image of that input and the segmented fluid filled region for that image is shown in fig. 2, fig. 3 and fig. 4 respectively.

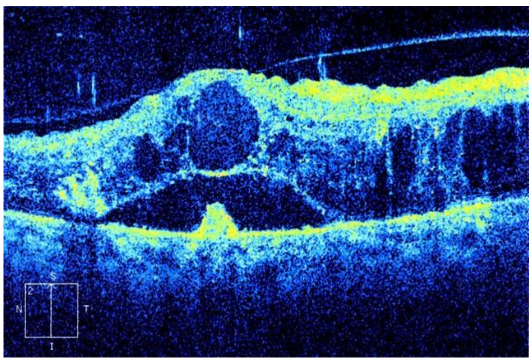

Fig. 2: Input image

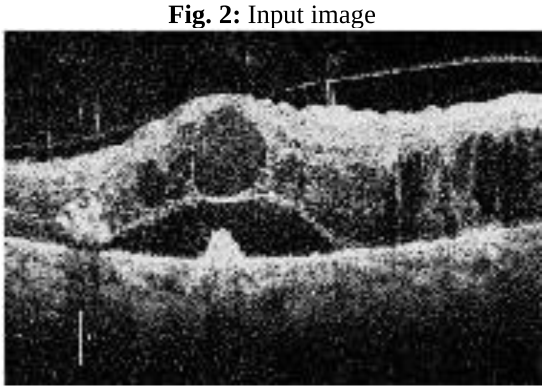

Fig. 3: Grayscale image

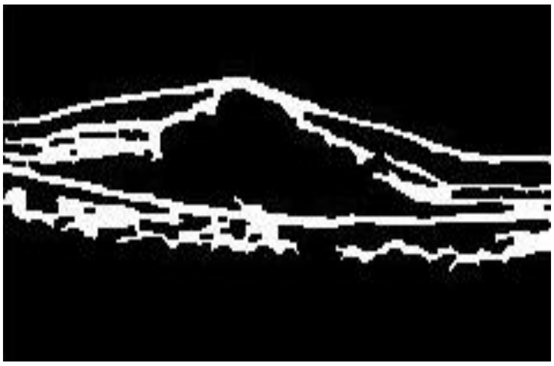

Fig. 4: Segmented image

Among the various classifiers used including the Random Forest classifiers, SVM classifiers and the k NN Classifier, it was found that the Random Forest Classifier and the k NN Classifier has similar accuracy whereas, SVM Classifier has a significantly lesser accuracy. The overall statistical parameters like sensitivity, specificity and accuracy were found to be more promising with the Random Forest classifier and the k NN classifier when compared to other methodologies as cited. Further improvisations shall be made by increasing the range of the abnormalities evaluated and identifying age related disorders. Also, several other tools and parameters like age, gender, morbidity, and other dominating factors shall also be taken into consideration to make the system more efficient towards the overall process of decision making.

CONCLUSION

The overall understanding of the implemented artificial intelligence-based decision making/ classification system for fluid related abnormalities of optical coherence tomography retinal images proves to be mandated in the current trends of diagnosis and therapy in the healthcare sectors. Most of the SD OCT devices have started to implement various efficient preprocessing techniques for speckle reduction to have a detailed picture of the regions/layers of retina. Importance of proper methodology of segmentation remains vital to understand the proper features that shall be used for further classification of the input ophthalmic images. The efficiency of the classifiers purely depends on the features used for classification and it is mandated to optimize the number of features and time taken for classification for implementing an efficient decision-making system. On efficient analysis it is understandable that the implementation of such a decision making/interpretation system would in turn help in proper efficient management of the healthcare resources.

CONFLICT OF INTEREST

Author declares no conflicts of interest.

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