Segmentational color map analysis to identify retinal detachment

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Abstract: The recent perilous times entails the importance of good health for humans. This can be pertaining the maintenance of good health in various organs of the human body. With the increase of digital platforms, and the necessity to stay longer hours with gadgets and electronic devices, the human eye takes a toll in terms of absorbing radiations that maybe harmful. An imperative check of the eye is essential from time to time, as the luminous membrane that aids in vision needs to hold firm to the various components within itself. Although there are various treatments associated with the detection of eye detriments, several gremlins tend to loom at large. These eye diseases can arise from numerous reasons ranging from genetic disorders to accidents and vision loss due to stimulated injuries, infections and dysfunctional development of tissues/cells/nerves within the eye. Retinal detachment (RD) is one of the profound problems that persist amongst many individuals scaling over a diverse range of ages. The risk in relevance to untreated detachment of the eye leads to purblind and sometimes complete loss of vision. The previous paper concerning retinal detachment of human eye has focused on various algorithmic and post-processing approaches, but failed to identify the origination and symptoms that could aid in meticulous diagnosis. The indagation in this paper pivots on the unsheathing of attributes that explicates the disassociation of the retina from the underlying layers of the eye using the fundus image with cost-effectiveness and swifter analysis. An important characteristic that is emphasized in this study is the segmentation of eye floaters in the vitreous fluid of the eye. These eye floaters are color mapped to identify the presence of detached tissues in the eye. The histogram analysis using the grayscale thresholding value further aids in providing a detailed distinction of the normal eye from the detached eye. The simulations are carried out in MATLAB, and the results have been obtained successfully.
1. Introduction

The human eye is a cardinal organ of the human body. This organ of the human body is compared and holds close relevance to a camera in the way that it processes the image through light and signal passing. The tri-layered structure of the human eye is segregated into chambers on the inner portion. Each layer holds significant importance in enabling vision. The sclera is the outer layer membrane which is opaque, and consists of the cornea with the mild bulge in front. The intermediate layer is the choroid, it is a vascular portion holding the tethering tissues which connect the membranes. This choroid coating lies between the sclera and the retina [15], and can have varying depths of thickness. Pro-centered in the choroidal layer is the iris, with a small aperture called as the pupil [8]. The inner-most structure is the retina which comprises of two sub-layers for visual, sensory processing and for signal generation [9]. The anterior, posterior and the vitreous chambers of the eye fulfill the functionalities of vision through the lens aperture and capturing the images using the macula in the retinal lobe. These chambers regulate the functioning of the retinal detailing, pupil contraction, vitreous fluid generation and maintaining the elasticity of the membranes [15]. The correlation between the retina, the fluids, lens and the cornea are depicted in the figure below.

![Anatomy of the Eye with relevance to Retina](image)

Fig 1. Anatomy of the Eye with relevance to Retina

The interrelation that the retinal blood vessels have with the concomitant parts helps in sending the right signal to the brain to effectuate normal vision. However, all these functionalities can be in jeopardy if there are any pre-existing diseases or genetically transmittable inherent detriments that may have an impact on the retina [1]. If the retina is not conjoined at the earlier phases, permanent vision loss may subsequently follow [10]. Depending upon the degree of detachment in the ocular region, RD can be stratified into rhegmatogenous, tractional and exudative [2], [7].

Retinal detachment in the most traditional form of clinical analysis is evaluated using the ultrasound-hinged mode of diagnosis. Ophthalmologists consider this tool of evaluation as irrefutably conventional mode of testing the defective retinal detached eye of an individual [5], [6]. Nonetheless, the challenges pertaining this ultrasound mode of evaluation lie in the obscure and non-transparent nature of the vitreous fluid that flows through the retinal membrane. This opaqueness can be caused due to the existence of bleeding, cataract and aberrations in the vitreous fluid, thereby making it an onerous task for light to seep through. Bio-medical depictions and representations in the form of Magnetic Resonance Imaging (MRI) [3], Optical Coherence Tomography (OCT) [4], color fundus photography [2] and ultrasound imaging modes of operation have been extensively explored for multifarious studies adopted for enhancing the diagnosis of the visual lurgies, malaises and detriments.

This paper analyzes to determine the attributes that constitute in giving rise to the detachment of the retinal tissues in the human eye. This distinct differentiation cognized between a normal human eye with no detachments, and one that holds disengaged tissues is analyzed through the histogram analysis of thresholding, and through the eye floaters which exceed in number in the vitreous gel. This agnizing of the symptoms usually take expensive scanning through clinical
procedures. The proposed indagation identifies these symptoms through mitigated costs and faster time of processing by utilizing the image processing and segmentation techniques. The paper is regimented with section II expounding the existing methodology, the proposed study is explicated in section III. Section IV delineates on the results, and the final section provides a compendium of the work with the future implementation to be done.

2. EXISTING METHODOLOGY

The existing research pertaining to retinal detachment have been explored in various domains and clinical practices. The ultrasonographic analysis have been used in various image pre-processing analysis [12],[13],[5] and detailed by various researchers in the field. The ROI detection of the detached section with adequate computation of the disassociated distance has augmented in identifying the tear more precisely [5], [6]. Further exploration on the existing methodologies also entailed the detachment identification by evaluating the thickness of the choroid gel through the percentage area calculation of the detached retina (PADR) [14].

3. PROPOSED INDAGATION

Retinal detachments are identified through a list of parameters that enable in analyzing the symptomatic changes in the human eye. These attributes may include the following and are not necessarily restricted to the below symptoms [16]:

- Increase number of eye flashes otherwise called as photopsia.
- Quantitative increase in the number of eye floaters in the vitreous fluid.
- Loss of vision.
- Mitigated peripheral vision.
- A lingering shadow over the visual cortex.
- Red clusters leading to dilated pupil
- Tunnelled vision
- Scarred retina leading to fibrosis.

The clinical practices and existing methodologies have had extensive research in identifying and precisely locating the tear of retina in the human eye. Nevertheless, the cause of origination is a lesser trodden path. The indagation presented follows a series of computational and pre-processing methods toagnize this germination of detachment for an individual through the segmentation of eye floaters observed in the vitreous humor. Figure 3 presents a graphical explanation of the sequence of evaluations done for identifying the number of floaters in the eye.

The data for processing is drawn from the STARE database. The RGB image is then converted to a grayscale image for initial preprocessing and noise reduction. Preprocessing bolsters the precision and interpretability of an image. The aim of pre-processing is to generate an improvised image that suppresses unwanted distortions, and parallely enhances some image features which are vital for further processing and characterization. An image with good quality helps in rendering the right pixel accuracy of the targeted features.
The reason for converting the RGB image to a grayscale image is to compress the image to lesser number of bits as compared to the former. The grayscale image can also help in swifter processing of the subsequent methods when compared to the RGB image. The ensuing step after this image transformation is the method of thresholding. The process of segmenting the image based on the pixel ranges is performed through this method [21]. This study utilizes the grayscale value for thresholding and converts it into a binary image comprising pixels which can either be 0 or 1. The image thresholding method is computed through the below formula [22]:

\[
f(m, n) = \begin{cases} 
1 & \text{if } g(m, n) \geq \text{Thresh} \\
0 & \text{Otherwise}
\end{cases}
\]

Where \( f(m, n) \) indicates the image procured from the threshold grayscale image pixel analysis, and the \( g(m, n) \) refers to the coordinate points \( m \) and \( n \) in the chosen image.

The next process of execution entails the histogram analysis which signifies the intensity distribution of the grayscale pixels in the image. This graphing method can also indicate the frequency of occurrence of a pixel value in the chosen image [17]. The histogram analysis for this study is depicted in the following section for a normal and a detached eye. Since this study focuses on identifying the parameters which best indicate the detachment of retina in the eye, the parameter of increasing eye floaters is taken into consideration. Eye floaters [23] are those that curtail the vision of the eye, and holds the property of floating in the vitreous fluid. Figure 4 depicts these structures more explicitly.

![Fig 3. Eye floaters in the vitreous gel](image)

In order to segment the number of floaters, it is necessary that the image holds different pixel intensity for the floaters observed in the vitreous gel. This motivated the incorporation of color-mapped pixel analysis [21], which helps in agnizing the structures that exist in the image. This is therefore implemented by using the label2rgb function that helps in perceiving the labelled compartments in different pixel intensities. The label matrix choses the intensity of the pixels based on the color map, pixel coordinate position and the quantity of structures that are to be labelled [20]. The outcome of this process helps in identifying the eye floaters which increase when there is detachment of retina. The region property [19] delivers the various attributes such as the area, centroid, eccentricity, orientation, pixel values, mean intensity, minimum and maximum intensities associated for the chosen image. These properties are a great aid in differentiating the retinal detached eye to that of the normal eye in a significant manner. The result of the cluster of processes is shown in the subsequent section.

4. SIMULATION RESULTS

The simulation of this study is executed in MATLAB, the initial process entails the original fundus image obtained from the STARE database to be given as input. The flow of execution is designed in a manner that any image when loaded, is converted to a grayscale image for further processing. Figure 4 illustrates the initial steps of implementation for the fundus image procured.
for retinal detachment.

Fig 4. Image Loading and Conversion to grayscale

The next outcome of the process is indicative of setting the grayscale value to perform the process of thresholding and histogram analysis. This grayscale value is fine-tuned according to the user’s perspective of the desired outcome from the image chosen. The value of grayscale chosen for this study is equated to 112 for the detached and normal eye. The ensuing result depicts the thresholding segmentation of the grayscale to a binary image along with the histogram result which identifies the pixel intensities observed for the same.

Fig 5. Histogram analysis and thresholding to obtain Binary Image

The final result is crucial in understanding the increase in the number of eye floaters observed when there is retinal detachment. The process of color-mapping illustrates the eye floaters more distinctively than what is observed in a normal eye. Figure 6 presents the color-mapped segmentation of the eye floaters which helps in the facile analysis of the detachment.
Fig 6. Segmentation using color-mapped intensity matrix

The following figure illustrates a comparison drawn between a normal eye and a detached eye, where the histogram variations and the absence of floaters in seen. This helps in understanding the analysis in a better manner.

Fig 7. Comparison drawn from a Normal eye (Left) and the Retinal Detached eye in the right

The result depicts the uniformity of peaks in the histogram for a normal eye, while the sudden peak in the detached eye. The normal eye also indicates that there are no floaters in the vitreous gel, while the floaters seen in the detached eye is higher in number. The region of area for the detached eye when compared to the normal eye also significantly increased due to the detached layers, this parameter also has been helpful in classifying the retinal detachment from the database of fundus images chosen as input.
5. CONCLUSION AND FUTURE WORK

Eye floaters have been a cause of concern for effective vision in a human eye. However, the emphasis of this study is to efficaciously identify, detect and process the detachment in the human eye as compared to a normal eye. The indagation has successfully analyzed a parameter that best depicts the origination of retinal detachment from its underlying layers. This comparison done between the normal eye and the detached eye can help in increasing automated approaches instead of physical presence of patients to identify the floaters in the vitreous humor. It also proffers better cost-efficacy along with mitigated time consumption. The future work entails analyzing more parameters relevant to the detachment of retina through computational procedures.

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