International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-7, Issue-6S4, April 2019

Retinal Nerve Fibre Layer Segmentation and Extraction of Retinal Features for Diagnosis of Glaucoma in Oct Images

M. Ponni Bala , T. Keerthanashree, K. Sheikdavood

Abstract**:** ***In the medical field, wide varieties of applications can be dealt using image processing. Detection and screening of retinal diseases is one such application in image processing. Glaucoma is terrible form of a disease in which the subject's optic nerve will be destroyed gradually which can lead to permanent loss of vision. Everyone is under risk from babies to senior citizens. The optic nerve is mainly composed of retinal fibers which are originated from the retinal ganglion cells. The optic nerve is considered like a bridge in between the retina and the brain. The retina is an area lying at the back of the eyeball. Optic nerve consists of delicate fibers which will be destroyed due to the excessive pressure due to glaucoma. Certain amount of fibers will be destroyed, which can lead to development of blind spots in the vision field. A patient's sight at initial stage affects the peripheral vision or side vision and progresses towards the central vision at the advanced stage. The exact causes of optic nerve damage for glaucoma involve decreased blood flow of the optic nerve. In Glaucoma, due to the loss of tissues in the surrounding the nervous tissue in the central cup seems to be as an enlarged one. In addition to thinning of the Retinal Nerve Fiber Layer, structural changes in optic nerve rim is considered as very important screening tool for Glaucoma .In this research work, segmentation of Retinal Nerve Fiber Layer and extraction of retinal features from the retinal OCT image is proposed, in which by verifying the retinal images, time and energy of the ophthalmologists is reduced to an extent. The Nerve Fiber Layer is segmented by Semi-Automatic Region Growing Technique. The thickness of Retinal Nerve Fiber Layer (RNFL) are calculated for 60 images from the segmented nerve fiber layer image Then, the texture based feature extraction is done for 60 images and these features are used for classification purpose. The features such as RNFL Thickness, GLCM and LBP features are used to diagnose the Glaucoma. Different stages of Glaucoma can be effectively classified using Multi-Class Support Vector Machine.***

Index Terms**:** ***OCT, SVM, RNFL.***

I. INTRODUCTION

Glaucoma is a retinal infection gotten from the difficulties brought about by the dynamic degeneration of optic nerve filaments and prompts basic changes of the optic nerve and a quick utilitarian disappointment of the visual field. At present, Glaucoma is considered as the Second leading main cause for blindness in peoples of 2.4% for all ages and 4.7% for ages above 75 years. Since, Glaucoma has no symptoms within the initial steps and the related visualization loss cannot be bring back, its before time detection and following behavior is essential to avoid further illustration harm. Aqueous humor fluid which is present in eye is drained through Canal. Intraocular pressure will be developed inside the eye if the fluid is not drained properly and accumulates inside. The infection is mostly cause due to enlarged Intraocular Pressure (IOP) resulting from a malfunction of the eye's drainage structures. There is a need for checking progression of Glaucoma in patients at early stage so that its progression can be controlled or necessary action can be taken. For this reason, ophthalmologists will frequently manage the retinal images acquire using the Optical Coherence Tomography (OCT) images for diagnosis of Glaucoma.

The infection is mostly reason due to enlarged Intraocular Pressure (EIP) consequential from a go wrong of the eye's drainage structures. There is a need for checking progression of Glaucoma in patients at early stage so that its progression can be controlled or necessary action can be taken. Due to this reason, ophthalmologists will frequently manage the retinal images acquire using the Optical Coherence Tomography (OCT) images for diagnosis of Glaucoma. The World Health Organisation (WHO) has estimated that Glaucoma is responsible for 25% of the 60.5 million cases of loss of sight through the world. In India, 12.8% of the 12 million people are affected by Glaucoma.

II. LITERATURE REVIEW

Extraction of retinal features:

The segmentation of Retinal Nerve Fiber Layer, Extraction of Retinal Nerve Fiber Layer (RNFL) thickness, Texture based feature extraction are carried out by many researchers, their published ideas and the final results of their works. By using two step kernel based optimization scheme, individual retinal layers are identified and segmented. The proposed method is utilized to an extent for processing and segmenting the OCT images with low contrast, speckle noise and irregular shape structural features.

Shijian Lu et al (2010) proposed a technique which can be used to diagnose the glaucoma which is an automated technique. To measure the thickness of RNFL layer the blood vessels was detected by Iterative Polynomial level procedure. OCT images are then sifted by a respective channel and a middle channel successively. At that point the edges of RNFL are distinguished and the edge fragments comparing to the layer limit are additionally recognized and grouped to frame the layer limit of OCT images proficiently.

Revised Manuscript Received on April 05, 2019.

Dr.M.Ponni Bala, Associate professor, Department of Electronics and Instrumentation, Kongu Engineering College, Erode, Tamilnadu, India

T.Keerthanashree, PG Student, Department of Electronics and Instrumentation, Kongu Engineering College, Erode, Tamilnadu, India

K.Sheikdavood, Assistant Professor, Department of Electronics and Communication Engineering, M.Kumarasamy College of Engineering, Karur-639113, Tamil Nadu, India.

Qing Dai et al (2011) proposed an automated boundary segmentation algorithm for quick and dependable evaluation of six intra-retinal boundaries in Optical Coherence Tomography (OCT) images. Initially pre-processing steps is done to remove speckle noise. Then the retinal blood vessels was detected and divided into multiple Non-vessel sections. The edge detection was done using local gradient information of the OCT images. To validate the segmentation algorithm independent manual segmentation has done. The obtained results have high accuracy and reproducibility in segmenting normal OCT images. Dhivyabharathi et al (2013) proposed an automatic thickness measurement of RNFL using OCT images was done. To segment the RNFL, an algorithm is developed with the help of extraction from the retinal layers in the OCT images. In pixel calculations the thickness of the RNFL is measured. Ponni Bala et al (2015) proposed a new method from the color fundus images for extraction of retinal blood vessels. By applying the pre-processing methods and segmentation techniques using matched filter and modified local entropy thresholding operation the blood vessels are extracted from the color fundus image. In this method, a newly developed machine learning algorithm called Extreme Learning Machine (ELM) is used for diagnosing the Proliferative Diabetic Retinopathy. Performance of ELM is compared in conditions of categorization exactness with Support Vector Machine (SVM) Classifier. It is observed that ELM leads to 97.5% average accuracy in comparison with SVM classifier (87.5%) for DIARETDB0 images. Mahdi Salarian et al (2015) showed a method of automatic extraction of all retinal layers, in which the finding RNFL layer is difficult to segment from the other layers. In common, the shortest path algorithm method was applied on the global gradient of an image, besides using general software for extraction of layers narrow search method such as Dijstra's algorithm, particularly designed for the next boundary. These results demonstrate high accuracy in segmenting the RNFL layer for diagnosis of glaucoma.

III. SEGMENTATION OF RETINAL NERVE FIBER LAYER

Glaucoma is a chronic degenerative eye infection that go ahead to serious visualization failure. It stands second which cause peripheral blindness by neuro degeneration of delicate nerve fibers. It can be identified only after the disease becomes sever. The ophthalmologists take time and energy of the professionals for manual screening and treating. Hence a innovative approach for the fragment of Retinal Nerve Fiber layer is proposed in this work.

The major objective of this effort is to segment the retinal nerve fiber layer and diagnose the Glaucoma by means of the features pull out from the segmented image. The images are collected from the Lotus Eye Hospital and Institute, Coimbatore which comprises of 60 RNFL-OCT images are exposed to the pre-handling steps, for example, green channel extraction and filtering. After pre-processing, the denoised image is subjected to Semi-Automatic Region growing segmentation technique. This segmented image is at that moment exploit for feature pulling out. The features such are RNFL thickness measurement and texture based properties are extracted from the retinal images. The appropriate features are selected and used for classification for diagnosing Glaucoma.

The block diagram of the proposed methodology of this project work is shown in Fig: 1.

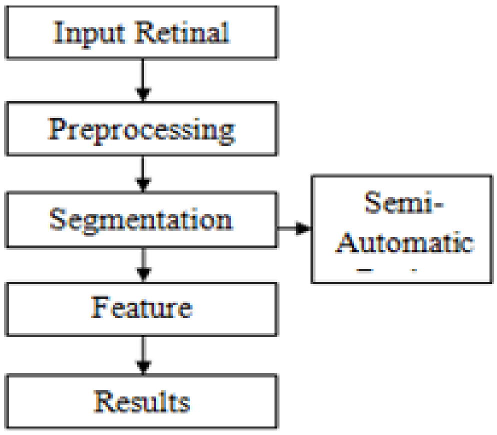


Fig: 1 Block Diagram

The input retinal images collected from the hospital are pre-processed to eliminate the unwanted noise commencing the image and then the denoised OCT images were used for further processing. Then, the Retinal Nerve Fiber Layer region is segmented by Region Growing segmentation technique. The Retinal Nerve Fiber layer is extracted from the segmented image and the RNFL thickness measurement, texture features is extracted for diagnosis of Glaucoma.

A. Retinal Image Acquisition

The dataset has been made based on participation with the Eye Hospital at the Lotus Eye Hospital and Institute, Coimbatore. The dataset so far contains 14 images of sound subjects with no indications of Glaucoma illness and 26 images of glaucomatous subjects. Notwithstanding the images, likewise data about the therapeutic discoveries must be accessible. The data about the medicinal discoveries is known as ground truth.

B. Image Preprocessing

In order to remove the unwanted disturbances present in acquired input retinal OCT images, pre-processing is required. The disturbances include noises and the poor illumination of the retinal images. The preprocessing includes green channel extraction and Filtering.

C. Green Channel Extraction

The green channel image contains the more measure of data since there is a higher differentiation between the vessel pixels and the non-vessel pixels. The red light is less consumed by the shades of the internal eye, and it commands the reflected range. This is the motivation behind why the shading fundus images seem ruddy. In view of the lower assimilation coefficients for red light, structures containing colors are less differentiated than it is the situation of green light. Fig: 2 shows the RGB channel of retinal fundus image. From the acquired RGB plane, the green channel of the RGB-representation shows the best contrast, that the red channel is often saturated (or at least the brightest color channel) and has low contrast, and that blue channel is very noisy and suffers from poor dynamic range.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

This does not mean that there cannot be any useful information in the red channel and blue channel. It just means that blood containing elements (vessels) in the retinal layer are best represented and have highest contrast in the green channel.

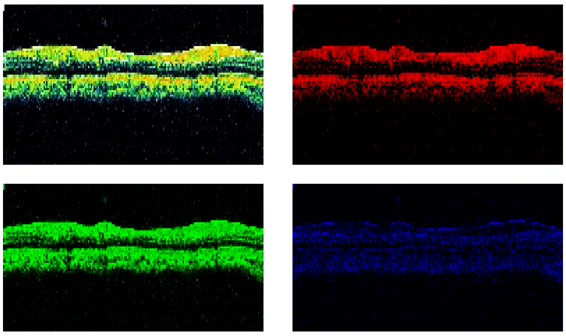
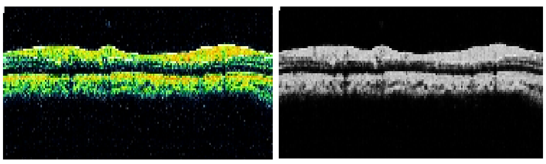


Fig: 2 RGB Plane Extracted OCT Retinal Image
a) Original OCT Image b) Red Channel Image c) Green Channel Image d) Blue Channel Image

D. Speckle Noise Reduction

Speckle emerges as a characteristic result of the constrained spatial-recurrence transfer speed of the impedance signals estimated in OCT. In images of very dispersing organic tissues, spot has as a double job as a wellspring of commotion and a transporter of data about tissue microstructure. With regards to optical lucidness tomography, the goal of spot decrease is to smother flag corrupting dot and highlight flag conveying dot. Among the most prominent image handling techniques for spot commotion decrease are middle separating, Bilateral sifting, Wiener sifting. The info image is changed over into a grayscale image. At that point by utilizing middle channel the image is sifted which avoids dot clamor. In this manner middle channel helps in both commotion expulsion and safeguarding the edges. Fig: 3 show the De-noised OCT image after pre-processing.



(a) (b)
Fig: 3 Filtering Results
a) Original OCT Images, b) De-Noised OCT Image

E. Semi-Automatic Region Growing Based Segmentation

The Region developing is a straightforward district based image division technique to fragment the Retinal Nerve Fiber Layer from the other intra-retinal layers of eye. It is additionally delegated a pixel-based image division technique since it includes the determination of starting seed focuses. This way to deal with division inspects neighbouring pixels of introductory seed focuses and decides if the pixel neighbours ought to be added to the area. The procedure is iterated on; in a similar way as general information bunching calculations. Locale developing methodologies abuse the essential reality that pixels which are near one another have comparative dark qualities. District developing methodologies is the inverse of the part and union methodology. The steps for selection of Seed Points are as follows:

STEP 1: A basic arrangement of little regions is iteratively converged by comparability imperatives.

STEP 2: Begin by picking a discretionary seed pixel and contrast it and neighboring pixels.

STEP 3: A district is developed from the seed pixel by including neighboring pixels that are comparable, expanding the extent.

STEP 4: At the point when the development of one area stops we just pick another seed pixel which does not yet have a place with any locale and begin once more.

STEP 5: This entire procedure proceeds until all pixels have a place with some local.

The Region Growing algorithmic steps are as follows:

Step 1: Calculating the mean of the window selected to act as mask

Step 2: Collecting the number of pixels in the mask region

Step 3: Assigning free memory to store neighbors of the (mask) region

Step 4: Initializing the distance of the region's new pixel to the region mean

Step 5: Initializing the neighbor locations (footprint)

Step 6: begin region growing until distance between region and possible new pixels

Step 7: Adding new neighboring pixels

Step 8: Calculating the neighbor coordinate

Step 9: Check if the neighboring pixel is inside or outside the region

Step 10: Add to neighbor if it lies inside and not already part of the segmented area

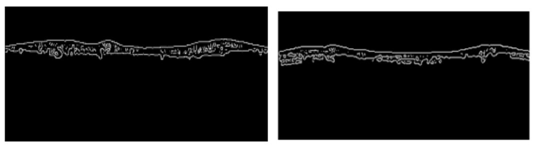
Step 11: Adding pixel to the region having intensity nearest to the mean of the region

Step 12: Calculating the new mean of the region

Step 13: Removing the pixel from the neighbour list

Step 14: Returning the segmented area as logical matrix

The retinal nerve fiber layer is segmented from other retinal layers of eye. The various edge detectors used to find the RNFL edges. From the RNFL edges, Canny edge detector produce better results for edge detection. Figure 4 shows the Edges of Retinal Nerve Fiber Layer using canny edge detector.



(a) (b)

Fig: 4 Results of Edge Detection in RNFL Layer
a) Normal Stage OCT Image,
b) Severe Stage OCT Image

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

IV. FEATURE EXTRACTION

Highlight extraction normally processes quantitative data from the divided items. The extricated highlights can be utilized to characterize objects as per foreordained criteria, for example, size, shading and surface for the appraisal of Glaucoma. The progression of disease was identified by RNFL thickness from the segmented Retinal Nerve Fiber Layer and also texture based feature extraction are performed to classify glaucoma as Normal stage, Mild Stage, Moderate stage and Severe affected stage. The texture features are extracted using statistical Haralick features namely GLCM and Local Binary Pattern.

The Retinal Nerve Fiber Layer (RNFL) thickness can be accomplished by computing the quantity of pixels. At first, the quantity of pixels in every section is determined and is duplicated with the goals factor (10 microns/pixels). At that point, the quantity of segments is determined. Thickness esteem along these lines determined is looked at for ordinary and strange pictures. The scope of thickness fluctuates likewise for each patient and it relies on the age of the patient.

Table 1

Normal RNFL Thickness Range(Microns)	> 90 Microns
Glaucomatous RNFL Thickness Range (Micros)	< 70 Microns

The Table 1 shows the baseline data for the assessment of Glaucoma from the measured RNFL thickness. In this proposed work, the RNFL thickness is calculated from the segmented RNFL layer. The computed RNFL thickness is used for Glaucoma screening. If it is greater than the threshold, indicates glaucomatous, otherwise it is healthy eye.

Texture Features

The surface investigation strategy is connected for highlight extraction and it is processed at the picture level. The first, called the measurable or stochastic methodology, regards surfaces as factual marvels. The arrangement of a surface is depicted with the measurable properties of the forces and places of pixels. Co-event insights and distinction histograms inquired about by Haralick et al, Weszka et al, and can fill in as straightforward instances of factual surface measures. These sorts of surface models work best with stochastic smaller scale surfaces. The LBP can be treated as an extraordinary instance of a multi-dimensional co-event measurement. The two strategies are chosen in light of their power to clamor, revolution and enlightenment invariant properties.

V. CLASSIFICATION USING MULTI-CLASS SUPPORT VECTOR MACHINE

The information OCT pictures are fragmented and the RNFL thicknesses are estimated, and the surface highlights are extricated from the resultant pictures. The removed highlights are given for multi-class SVM classifier in which order precision and approval of seriousness dimension of illness are recognized. Support Vector Machine (SVM) was presented by Vapnik and it is another learning technique utilized for paired order. SVM is a managed arrangement technique. Here, a lot of realized articles is called preparing set. Each object of the preparation set comprises of an element vector and having place class esteem. In view of the preparation information, the learning calculation extricates a choice capacity to order the obscure information. To stretch out SVM to the multi-class situation, various grouping models were proposed, for example, the one by Crammer and Singer. Support vector machine (SVM) initially isolates the paired classes (k = 2) with an augmented edge measure. Nonetheless, genuine issues regularly require the separation for multiple classifications. Therefore, the multi-class Support vector machine has a wide scope of uses including optical character acknowledgment, interruption location, discourse acknowledgment, and bioinformatics. At the point when contrasted and another traditional classifier, Multi-Class Support Vector Machine (SVM) is utilized for characterization in the proposed work. It has numerous preferences, for example, quick intermingling and lessens the inquiry space measurement of the ordinary back spread system.

VI. RESULTS & DISCUSSIONS

Segmentation results of **NORMAL** SD-OCT images are shown in Figure 5.

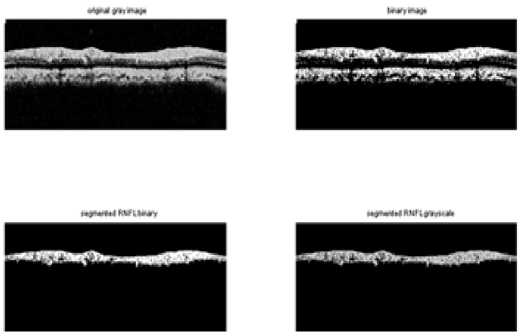


Fig: 5 (a) Original Gray Image (b) Binary Image (c) Segmented RNFL Binary (d) Segmented RNFL Grayscale

Segmentation results of **SEVERE** STAGE SD_OCT images are shown in Figure 6.

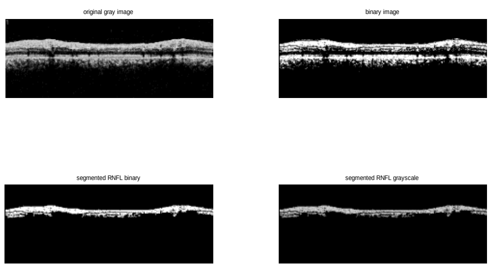


Fig: 6 (a) Original Gray Image (b) Binary Image (c)

Segmented RNFL Binary (d) Segmented RNFL Grayscale
The results of canny edge detection are shown in Figure 7.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

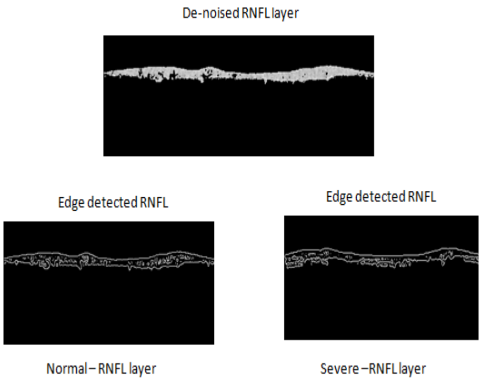


Fig: 7 (a) Denoised RNFL layer (b) Normal Edge detected RNFL layer (c) Severe Edge detected RNFL layer

The results of thickness measurement are shown in Table 2.

TABLE 2

Image	Obtained results	Stages of Glaucoma	Ground truth
Image 012	100.57	Normal	101
Image 020	93.229	Mild	95
Image 008	85.037	Mild	86
Image 043	79.61	Moderate	80
Image 050	78.57	Moderate	79
Image 022	63.33	Abnormal	64
Image 010	69.129	Abnormal	68
Image 003	59.772	Abnormal	57
Image 009	60.532	Abnormal	58
Image 007	57.23	Abnormal	61

Multi- Class Support Vector machine is use to classify the descriptions as Normal, Mild, Moderate and Severe stage of Glaucoma and the parameter selected and performance results are shown in Tables 3 and 4.

TABLE 3: Classification Parameter

Classification Parameter	Test Result
True Positive (TP)	14
False Positive (FP)	0
True Negative (TN)	05
False Negative (FN)	01

TABLE 4: Performance Results of Multiclass SVM classifier

Performance Metrices	Metrics Value (%)
Sensitivity (%)	**93.33**
Specificity (%)	**100**
PPA(%)	**100**
Accuracy (%)	**95%**

VII. CONCLUSION AND FUTURE SCOPE

Glaucoma is a noteworthy reason for visual impairment because of changes in eye weight. Likewise, it makes harm the optic nerve that conveys data from the eye to the mind. A proficient calculation for division of nerve fiber layer in OCT pictures utilizing the Semi-Automatic Region Growing based Segmentation has been presented. This technique performs great in extricating the Nerve Fiber Layer. The Nerve fiber layer are best of the intra-retinal layer and this technique performs proficiently in recognizing Retinal Nerve Fiber Layer from other layer additionally it safeguard the structure subtleties of picture and edges of RNFL. The proposed strategy holds the computational straightforwardness. The principle point of this venture is to remove Retinal Nerve Fiber Layer and arrange the OCT pictures dependent on the RNFL thickness and Texture highlights separated from the pre-handled picture and to give the Diagnosis of Glaucoma utilizing Classification procedure. The RNFL OCT eye pictures gathered from Lotus Eye Hospital and Institute are utilized for assessing the execution of Nerve Fiber Layer. The pre-handling steps incorporate green channel extraction, Filtering and after that division of Retinal Nerve Fiber layer incorporates Region Growing Segmentation Technique. The removed RNFL thickness esteems, surface highlights, for example, GLCM, LBP is utilized to analyze the seriousness of ailment. At that point, the removed highlights are utilized for further handling of order. In which, the Multi-class Support Vector Machine is utilized to characterize the pictures as Normal, Mild, Moderate and Severe Stage of Glaucoma.

The scope for future of the present research work is to extract the different features such as Bruch's Membrane Opening rim-width and Structural changes of Optic Nerve Head for Glaucoma using new segmentation technique to diagnose the OCT images with improved Sensitivity and Accuracy.

REFERENCES

1. Dhivyabharathi , Ganeshbabu and Venkatesh Rengaraj (2013), 'Measurement of RNFL Thickness Using OCT Images for Glaucoma Detection', ICTACT Journal on Image and Video Processing, Vol.4, No.1, pp.637-641.
2. S.Vijayprasath, S.Palanivel Rajan, "Performance Investigation of an Implicit Instrumentation Tool for Deadened Patients Using Common Eye Developments as a Paradigm", International Journal of Applied Engineering Research, ISSN No.: 0973-4562, Vol. 10, Issue No.1, pp. 925-929, 2015.
3. Durgesh K Srivastava, Lekha Bhambhu (2009), 'Data Classification using Support Vector Machine', Journal of Theoretical and Applied Information Technology, Vol.12, No.1, pp. 146-152.
4. Ganesh Babu.TR, R. Sathishkumar, Rengaraj Venkatesh (2014), 'Retinal Nerve Fiber Layer Segmentation of OCT Images by Entropy Method' Research Journal of Pharmaceutical, Biological and Chemical Sciences, Vol.5, No.5, pp.1397-1403.
5. Harish Sahu, Praveen Bhanodia (2013), 'An Analysis of Texture Classification: Local Binary Pattern', Journal of Global Research in Computer Science, Vol.4, No.5, pp.17-20.
6. S.Palanivel Rajan, "Review and Investigations on Future Research Directions of Mobile Based Telecare System for Cardiac Surveillance", Journal of Applied Research and Technology, ISSN No.: 1665–6423, Vol. 13, Issue 4, pp. 454-460, 2015.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

7. Mahdi Salarian, Rashid Ansari, Justin Wanek, Mahnaz Shahidi (2015), 'Accurate Segmentation of Retina Nerve Fiber layer in OCT Images', Journal of European Union, Vol. 30, No.12, pp.653-656.
8. S.Palanivel Rajan, "A Significant and Vital Glance on "Stress and Fitness Monitoring Embedded on a Modern Telematics Platform", Telemedicine and e-Health Journal, ISSN: 1530- 5627 (Online ISSN: 1556-3669), Vol. No.: 20, Issue No.: 8, pages: 757-758, 2014.
9. Odstrcilik.J, Kolar R, Tornow R.P, Budai A, Jan J, Mackova P, Vodakova M (2015),'Analysis of Retinal Nerve Fiber Layer Texture Related to the Thickness Measured by Optical Coherence Tomography', Developments in Medical Image Processing and Computer Vision: Lecture Notes in Computational Vision and Biomechanics Springer, pp.19-28.
10. Ponni Bala M, Vijayachitra S (2014), 'A Sequential Learning Method for Detection and Classification of Exudates in Retinal Images to Assess Diabetic Retinopathy', Journal of Biological Systems, Vol.22, No.3, pp.413-428.
11. S.Palanivel Rajan, et.al., **"**Visual and tag-based social image search based on hypergraph ranking method", IEEE Digital Library Xplore, ISBN : 978-1-4799-3835-3, INSPEC Accession Number : 14916051, DOI : 10.1109/ICICES.2014.7034079, 2015
12. Ponni Bala M, Vijayachitra S (2015), 'Extraction of Blood Vessels and Diagnosis of Proliferative Diabetic Retinopathy using Extreme Learning Machine', Journal of Medical Imaging and Health Informatics, Vol.5, pp.248-256.
13. Qiang Chen, Theodore Leng, Luoluo Zheng, Lauren Kutzscher, Jeffrey Ma, Luis De Sisternes (2013), ' Automated Drusen Segmentation and Quantification in SD-OCT Images', Journal of Medical Images Analysis Elsevier, Vol.17, pp.1058-1072.
14. Quigley. H.A., Broman. A.T (2006), 'The number of people with glaucoma worldwide in 2010 and 2020', British Journal of Ophthalmology, Vol.90, No.10, pp.262–267.
15. Ravi Thomas and Rajul S Parikh (2006), 'How to assess a patient for Glaucoma', Community Eye Health Journal, Vol.19, No.59, pp.36-37.
16. Radim Kolar, Ralf P. Tornow, Robert Laemmer, Jan Odstrcilik, Markus A. Mayer,
17. S.Palanivel Rajan, V.Kavitha, "Diagnosis of Cardiovascular Diseases using Retinal Images through Vessel Segmentation Graph", Current Medical Imaging Reviews (Bentham Science Publisher), Online ISSN No.: 1875-6603, Print ISSN No.: 1573-4056, Vol. No.: 13, Issue : 4, pp. 454-459, (Impact Factor– 0.613), 2017.
18. Rajendra Acharya.U, Sumeet Dua, Xian Du, Vinitha Sree S, Chua Kuang Chua (2011), ' Automated Diagnosis of Glaucoma using Texture and Higher Order Spectra Features', IEEE Transactions on Information Technology in Biomedicine, Vol. 15, No. 3, pp.449-455.
19. Rajan P S Davood S K (2015) Performance Evaluation on Automatic Follicles Detection in the Ovary International Journal of Applied Engineering Research Vol 10 No 55 Pages1-5.
20. Sheikdavood K Mahamudha P Nagendran K (2015) Performance Evaluation on Accurate Coronary Centerline Extraction and Catheter Detection in Angiographies International Journal of Applied Engineering Research Vol 10 No 1 Pages 349-353.
21. Sheikdavood K Surendar P Manikandan A (2016) Certain Investigation on Latent Fingerprint Improvement through Multi-Scale Patch Based Sparse Representation Indian Journal of Engineering Vol 13 No 31 Pages 59-64.
22. Sheikdavood K Palanivel Rajan S (2016) Analysis of Ovarian Diseases Using Ultrasound Images Journal of advances in chemistry Vol 12 No 10 Pages 4449-4454.
23. S.Palanivel Rajan, R.Sukanesh, "Viable Investigations and Real Time Recitation of Enhanced ECG Based Cardiac Tele-Monitoring System for Home-Care Applications: A Systematic Evaluation", Telemedicine and e-Health Journal, ISSN: 1530-5627, Online ISSN: 1556-3669, Vol. No.: 19, Issue No.: 4, pp. 278-286, 2013
24. S.Palanivel Rajan, et.al., "Experimental Explorations on EOG Signal Processing for Real Time Applications in LabVIEW", IEEE Digital Library Xplore, ISBN : 978-1-4673-2047-4, IEEE Catalog Number: CFP1221T-CDR, 2012.