FOR EFFECTIVE, EARLIER AND SIMPLIFIED DIAGNOSIS OF RETINOPATHY OF PREMATURITY (ROP), A PROBE THROUGH DIGITAL IMAGE PROCESSING ALGORITHM IN B-SCAN

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Abstract- Of all the senses, eye is the most vital, that animates light and enables us to view and enjoy the beautiful environment around us. The complex anatomy of eye comprises of several miniature layers, tissues and chambers, surrounded by protective layers and walls. Retina and its layers, situated at the dorsal region of the eye are responsible in enabling us to view the objects. Being such important in providing us the vision, Retina in-fact is more prone to many vision threatening disorders. The condition Retinopathy of Prematurity (RoP) is one of the conditions where retinal abnormalities are observed. It majorly affects in preterm infants. B Scan is the commonly used primary investigation technique used by an Ophthalmologist to diagnose RoP. In this paper, a series of latest methodologies and investigation tools useful for earlier, effective diagnosis of RoP and its management are reviewed. An algorithm is proposed which shows novelty in the methodology to measure the percentage deviation in the health of retina, in comparison with the prior B scan image. It is made simplified for the classification of stage of RoP based on the severity, location of abnormality and age of the patient which can be observed well in the Ultrasonic B Scan images. It is observed that the proposed algorithm and its design would be promising in providing an effective and simplified tool for Ophthalmologists for better diagnosis and management of RoP in infants and hence prevent artificial blindness.

Index Terms- Retinopathy of Prematurity (RoP) in infants, Health of Retina, Stage and Severity of RoP, Location of Retinal abnormality, Ultrasonic B Scan images, Diadic transformation and Least Square Filtration

1 INTRODUCTION:

In a Sanskrit verse, "Chakshu Rakshaayaam …….. Vidyee" which means, All-out efforts should be made by men to protect the eyes, throughout the period of life; for the man who is blind this world is useless, the day and night are the same even though he may have wealth, says Sri Vagbhada in Ashtanga Hridaya, Timira Pratisheda Adhyaya. In correlation with modern science, it is very significant in understanding the importance of eye and vision to witness the beautiful world around us. Eye is the organ in our human body which gives visual simulation and send the impulses to brain through optic nerve. The eye, which is a complex anatomical structure, is formed by very miniscule tissues and cells which are well protected by tough, skeletal walls. Of all the layers of eye, retina and its sub layers, which are similar to modern day's digital camera, are the most important ones for perception of light. Any abnormality in the structure or functioning of Retinal sub layers which comprises of blood vessels, nerve fibres, tissues, rods, cones, etc lead to significant visual difficulties and may cause blindness too. In general, the diseases affecting retina and its layers are terms as Retinopathy.

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Some of the retinal diseases commonly seen in India and across the world in the modern days are Retinal Detachment, Diabetic retinopathy, Proliferative Diabetic Retinopathy, Hypertensive Retinopathy, Retinal Scar, Macular degeneration, Choroidal Neovascular Membrane, Epiretinal Membrane, Macular hole, Viral Retinitis, Retinitis Pigmentosa, Behcet's syndrome, Coats disease, Retinopathy of Prematurity, etc. Out of all these, Retinopathy of Prematurity (RoP) is the congenital condition that affects preterm babies in the very early childhood and hence challenging to halt the artificial blindness. It is a vaso-proliferative, preventable disorder, chiefly observed in preterm new born infants (born within 31 weeks). The infants born with low birth weight (less than 1750gms) are also prone for getting affecting with RoP. In 1984, a committee has put forth world wise standards for the diagnosis of RoP and drafted the International Classification of ROP (ICROP). According to this, the site and stage of retinopathy can be identified based on the Zones and the extent to which the blood vessels have been affected. In this paper, the latest research work done in the diagnosis of RoP and its assessment.The classification of RoP happens in the following way. By considering the optic disc as the centre, three concentric circles are made on the retina, corresponding 3 zones. On the other hand, the degree or stage of retinopathy is classified into 5 stages, based on the vascular distribution along the retina. Demarcation line, Ridge, Ridge with extra retinal fibro vascular proliferation, Subtotal retinal detachment and Total retinal detachment are the five major stages of RoP. For an ease in understanding, RoP can be classified as mild disease, medium or pre-plus disease and severe or plus disease, very severe condition called aggressive posterior RoP or rush disease. also. Previously, it was assumed that decreased oxygen levels in the premature infants cause RoP. Later on, with the

practical observations, it was observed that the infants who are supplied with abundant oxygen in the incubator also suffer from the same. By considering the cyanosis of the preterm infant, incubator oxygen level, arterial oxygen tension monitoring, it is concluded that oxygen therapy has to be monitored very cautiously based on the requirement of an individual infant. The primary stage or vasoconstrictive phase experiences a decrease in the vascular endothelial factor. In the secondary or vasoproliferative stage, the sudden surge of vascular endothelial growth factor takes place due to the tortuosity and dilation occurring in bigger vessels, neovascularization, etc. Here, additionally blood vessels will proliferate into vascular membrane.

2 Literature Survey and Outcomes

It's been observed that appreciable amount of research is been taking place across the globe for effective understanding RoP and diagnose its symptoms in the earlier stages so that adverse effects can be prevented. Here is the gist of important observations made by the scientific community for effective diagnosis of RoP at the earliest possible time.

(1) The measurement of tortuosity of single blood vessel and network of blood vessels has been carried out by a simple, computationally efficient, algorithm, called as Automatic Image based method. The values attained are in-line with clinically perceived tortuosity measurements. The tortuosity of publicly available data bank and two other personal data banks is measured by calculating the curvature, indicating the curve's local inflection. In order to attain the exactness in the calculation of curvature by eliminating the linearity against the curvature, two changes are proposed in the commonly used Template Disk Method. It has been found that automatic image based method is more efficient in terms of correlation for vessel tortuosity and curvature's non linearity than the other existing systems in the state of the art.

(2) had developed a tool in order to reconstruct the 3D Pseudo retinal images, so that the stage of RoP can be segregated as 1, 2, 3 and 4. Totally, 37 images are tested, which includes 5 healthy eyes images also. The results are analysed and noticed that 95.83% of sensitivity and 96.55% of accuracy had been achieved.

(3) By identifying and extracting the images that feature the blood vessels and vessel segments in the retina so that the important identifications of RoP like Arterial Tortuosity and venous dilation can be diagnosed. While representing the image by extracting the features of vessels and segments through statistical approach by calculating the maximum, minimum and mean values, the assessment is not accurate as they represent both normal and abnormal vessels. In order to overcome this, a contemporary methodology named two-component Gaussian Mixture Model (GMM) has been proposed for extracting the features of an image. The model has been experimented on 77 images and found it 90% better compared to classical statistical methods. Also, the arteries and veins are distinguished accurately from the whole image, compared to the other conventional methods.

(4) Now-a-days, the low resolution or dark image processing methodologies are being used in order to segregate and extract the blood vessel structure from fundus or B scan. The signal matched filter helps identify the vascular anatomy of the retina and the binarised vascular network can be attained from the Matched Filter and First Order Derivative of Gaussian method (MFFDOG). In this proposed method, the gray scale images are of vessel networks are differentiated by applying original matched filter so that the vessel networks can be segmented as a binary image. The techniques of adaptive thresholding and matched filter hard kernel (MFHK) are applied on the binary image obtained. By assessing these techniques on 50 images, MFFDOG and MFHK have been proven to be a generalised and efficient method for diagnosis of RoP in children.

(5) The retinal disorders can be assessed thoroughly by segmenting the blood vessels based on the abnormalities found. In this study, the common problems caused in automated vessel segmentation are focused in designing a novel system which is Size Invariant Fully Convolutional Neural Network (SIFCN). The image patches with their equivalent pixel labels, the sequential convolution layers, pooling layers are fed as input, which helps to understand the basic qualities of retinal blood vessel segment. The features of blood vessel network can be understood based on the qualities of the segment. Instead of retinal blood vessel segmentation through pixels, better efficiency and accuracy have been achieved through Patch wise segmentation. Also, the maintenance of spatial information and up sampling are not essential. The accuracy of SIFCN is 0.9471 and Non Overlap SIFCN is found to be the best model for deep learning approaches with 31.17 and 3.68 seconds per image respectively.

(6) The Wide Field Imaging by Newbie technologies is one of the propitious ones to diagnose RoP compared to the conventional ones like binocular indirect ophthalmoscope. This paper comprehends various studies conducted and the advancements taken place in the evolution of biomedical imaging and instrumentation tools for earlier prognosis of RoP.

(7) The Accurate Major Temporal Arcade Detection benefits the prognosis of various diseases affecting retina, which are generally termed as Retinopathy. In this proposed system, the vascular tree is obtained by using Gabor filter. Here, the Major Temporal Arcade is symbolised as a skeletal image captured by automatic tracking algorithm. Phase portrait analysis is used to identify the centre of optic nerve head and morphological operations are performed on the image. On 20 sets of images each, the techniques of hand drawn trace and Major Temporal Arcade are applied. It is found that MTA, which is analysed by calculating the mean distance to the closest point, shows the error which is lesser by 2 pixels per MTA skeleton image compared to the earlier one. So, this algorithm can be applied in the prognosis of retinal disorders like diabetic retinopathy, macular edema, RoP, retinal scar, etc.

(8) The Plus disease in the case of RoP can be made evidential by the exact identification of tortuosity in the retinal blood vessels, which can be found by studying the variations attained through the computer aided diagnosis. Here, a method is proposed in order to identify and segment the retinal blood vessels, represent tortuosity quantatively and to take a decision with respect to the input parameters of healthy eye. The clinical examinations and

the outcomes of the proposed algorithm for 110 images (19 cases of RoP Plus Disease) are reviewed and observed sensitivity as 0.89 and specificity as 0.95 which shows this as one of the most preferred ones for real time applications.

(6) A Multiple Instance Learning methodology is proposed, where the images showing most probable matching with the featurs of the RoP condition are captured using a digital RetCam and plotted on a miGraph, which segregates the features extracted as per the matching with expected characteristics of RoP image. In this method, a set of images are taken with a grid representation, where every element is represented as a Patch. By analysing the individual patch features, the overall impressions are constructed by grouping the ones belonging to the particular image. The individual elements are labelled and groups as a whole are attributed as bags, which are supplied as inputs to MIL classifier for segregation. As per the experimental analysis, it's been concluded that the proposed approach is novel and effective in the diagnosis of RoP.

(9) The RoP prediction is conducted by the application of Support Vector Machine model as a conditional component in the discrete Conditional Phase type model. The other one called as Survival Component uses Coxian Phase type Distribution to establish the survival distribution, for which the relationship has to be established with the covariates of the conditional component. Several outcomes that are classified by Support Vector Machine are used as deterministic parameters to predict the probability of developing RoP in the child. In order to overcome the ambiguous predictions made due to class imbalances, a modern class decomposition technique, which is capable of handling with multiple class imbalances has been introduced. The required length of stay in paediatric or neonatal ward can be determined with the use of SVM classification outcomes and 5,8 ot 9 phase Coxian distribution.

(10) A semi-automatic computer based method in order the screen the presence of Plus disease of RoP, which is characterised by increased tortuosity and expanded width of retinal blood vessels. The blood vessels and their orientations shown in the image are identified as separate pixels by adopting Multiscale Gabor filters. The overall sensitivity of 1.0 and specificity of 0.92 are observed on the blood vessel mapped final images that are obtained after performing morphological image processing and Gabor filtering. A set of 50 images from KIDROP Bangalore are segregated either as the cases of RoP plus disease, intermediate stage or normal cases by the qualitative assessment of tortuosity and width of blood vessels, represented in the form of vessel map in every image.

(11) It is noticed that computer aided automated systems available in diagnosing RoP are showing more variations with respect to the clinical outcomes by the expert. In this paper, in order to reduce this gap an unsupervised model capable of representing severity index in the continuous form has been proposed instead of discrete classification. The representations of images take place as per the distribution of their functions but not as per the bulk statistical features which helps in the reduction non-linear dimensionality. The distance between the samples that is reflected as the distance between the distributions. By experimental verification on 104 wide angle images of retina, this unsupervised, continuous approach has found assuring by overcoming the mentioned challenges.

(12) Retinal vessel segmentation, which is one of the primary assignments in the diagnosis of any systemic illness affecting retina, is found to be challenging in terms of accuracy by using computer aided fundus image analyser. Here, the information about the retinal blood vessels is extracted directly through an unsupervised automatic, computationally compatible, morphological approach. The modified top-hat transforms and its mathematical morphology helps in pre-processing stage and segmentation of retinal blood vessels is carried out by hysteresis thresholding. By evaluating the DRIVE data in comparison with the earlier approaches, the proposed method attains an accuracy of 95.95% on an average and 97.01% at maximum, which makes this model efficient.

(13) It is stated that the process of Pollination, which is a natural system in the angiosperms, is the basic idea behind the proposed Flower Pollination Search Algorithm (FPSA), used to segregate the retinal blood vessels automatically. Based on certain predefined conditions, the image of the retina undergoes optimal clustering, where the FPSA frisks for the optimum, compact clusters. Any of the local search methods are applied to attain the features like shape and improve the outcomes of clustering. By testing on the data of images available in public, the proposed system demonstrates better outcomes with respect to accuracy, sensitivity and specificity.

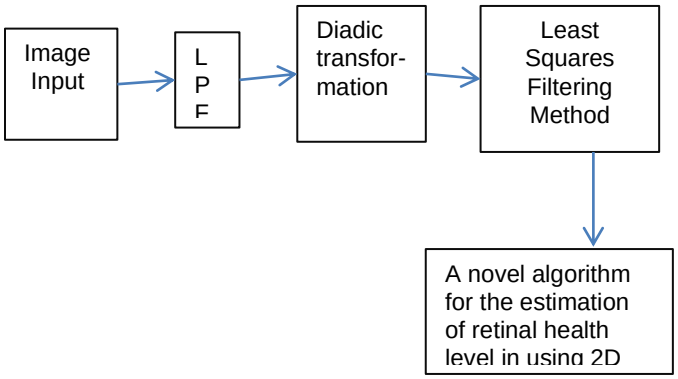
(14) A method has been proposed which helps the Ophthalmologist in identifying the stage of RoP as mild, medium or severe based on the results of automatic tortuosity measurement. In this, with the help of the original image, the outline structure of retina is obtained and morphological operations are performed to trace out the nodes, branches, terminals, etc as per the alignment of blood vessels. The process of segregation and rotation of each branch occurs in a simple repeated fashion. The segmented vessels are found to be useful to evaluating the tortuosity in 25 images.

(15) It is mentioned as many of the digital imaging systems are not found up to the mark in capturing the internal structures of the infants' eye, a novel methodology has been proposed which works well by providing an accurate, determinable measurement with low contrasted, disturbed, blurred images of premature infant. By implementing sparse tracking scheme, the retinal blood vessels available throughout the centre line of wide field images are derived automatically. The group of seed points are joined in the most cost effective path and weights which enable the vessels' tracing. The custom line operator calculates the features and their corresponding positioning. For a trail made on a data of 20 images captured from RetCam fundus, this model has shown 0.78 sensitivity and clinical outcomes are deviated at a rate of 0.15.

(16) It is aimed at providing quantitative and reproducible parameters to the Ophthalmologist by estimating the tortuosity of retinal blood vessels through a wide field fundus camera. Tortuosity parameter is estimated on 20 error free, manually outlined images. Various stages of vessel distribution and their tortuosities are measured and merged in a careful approach so that the tortuosity index

can be replicated in line with the clinical evaluations. An expert committee comprising 3 clinical graders and 3 retinal image analysts are involved in the manual, individual tortuosity measurement. It is found that the method has sown better results than the clinical outcomes by providing Spearman's correlation coefficient as 0.95 with ground truth.

3 Block Diagram of Proposed Methodology:



4 Proposed Instruments for Research:

The most commonly used reliable tool for diagnosis and assessment of RoP is Ultrasonic B scan. For the images with a higher quality and clarity, this study is conducted by using the images that are captured by portable Sonomed Escalon's, Master-Vu B-Scan (Model No: MV5600). This device can be is compatible to be connected to laptop/ PC. Hence, it can even be used as a bed side imaging system, based on the mobility of the individual. The hand held probe is moved gently on the surface of the closed eye and the no-sound sonic waves of 12MHz frequency entering the eye captures the fine quality still images and looped video clips on different frames. It is a sensitive, painless diagnostic tool that enables to read fine, miniscule internal structure of the eye. It neither affects the corneal curvature nor causes any compression of layers of eye. The brightness based B-scan and Amplitude based A-scan images can also be viewed simultaneously. The system features special modes for variable zoom, brightness and contrast control, 256 gray scale levels, pan and optimised area selection, annotation of on-screen, frame rate ID of 30fps (max) are notably available. The Scan depth adjustment of 30-60mm is useful to attain best penetration and acoustic output. Sonomed Escalon's, Master-Vu B-Scan has 0.015mm (max) and 0.1mm is the possible electronic and clinical resolutions respectively. The precision of distance is 0.046mm. The precision in terms of angle is ½ degree. The images captured through the ultrasonic probe can be viewed on the inter-phased monitor and can be saved as .jpg or .bmp files and continuous video can be saved as .wmp to the maximum of 100 frames. The software has a license to be installed in multiple computers or laptops and so, more number of ophthalmologists can use a single machine for easier screening of RoP using B scan. The individual's data base can be entered and saved as separate files in order to retrieve easily and protect patient's privacy. The observed clinical accuracy is +-0.1mm, electrical accuracy is +-0.32mm, lens database is 1600 and an increment of lens calculation is in 0.25D. Binkhorst, Regression II, Holladay, Hoffer Q, Haigis, etc are used to calculate intraocular lens power. Post refractive IOL calculation is carried out by Latkany myopic regressions, latkany hyperopic formula, Aramberri Double K, etc.

5 Sample B Scan Images:

Here are a few sample B Scan images with significant changes in retinal health. The normal retina and abnormal one are presented for better understanding. The left side images are of right eye and right side images are of left eye. It is essential to understand the anatomy of eye, especially retina for better understanding of proposed algorithm.

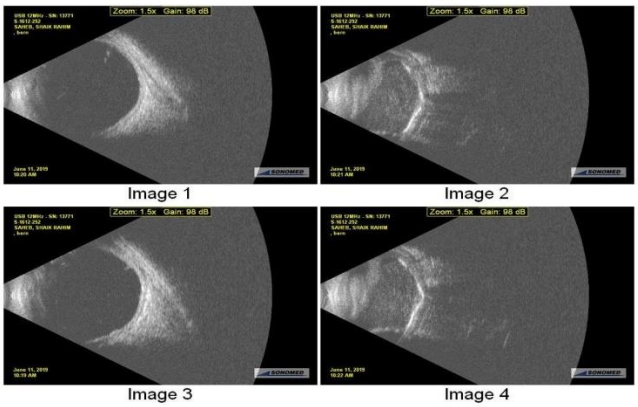


Image A: In right eye (OD), there is a mild degree of posterior vitreous detachment and hard exudates. In left eye (OS) the structure of eyeball is not well defined.

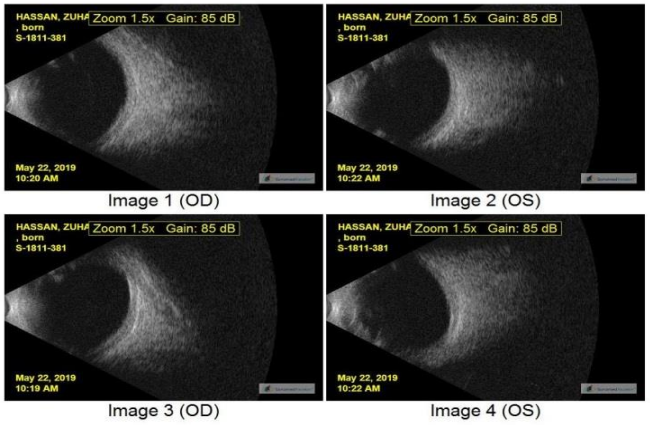


Image B: The health of retina is normal in both right (OD) and left (OS) eyes and mild floaters are observed.

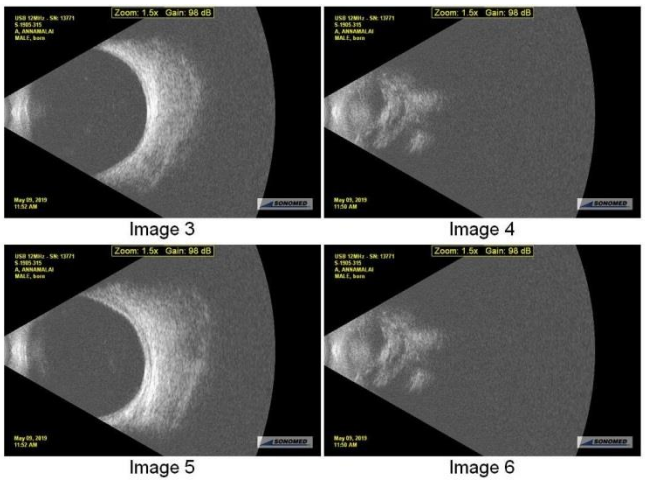


IMAGE C: Right eye (OD) has a normal retinal structure with mild floaters. Left eye (OS) has ill-formed retina with improper structure and uneven vitreous chamber.

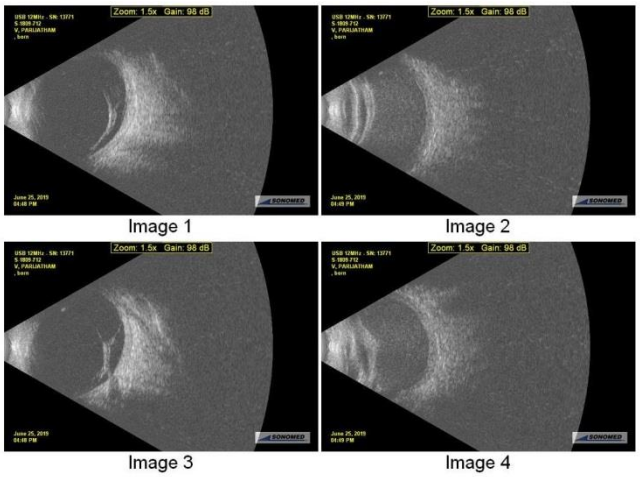


IMAGE D: In Right eye (OD), tractional retinal detachment is observed and in the left eye (OS), there is total retinal detachment.

6 CONCLUSION:

Here the images that are considered as sample are allowed to undergo all the changes as per the stages in the proposed algorithm. It is understood that there is an encouraging scope to attain exact percentage deviation of retinal health in comparison with prior ultrasonic B scan image. Also, enable us to understand the location and severity of the condition by accurate staging of the RoP condition. The staging technique considers the approximate age of the patient also. This algorithm has a scope where several unnoticed parameters in the usual examinations can be noticed with utmost precision and ease and hence would be a promising tool in real time applications for effective, earlier and simplified diagnosis of RoP in infants. It is strongly believed that this technique which would enable us to provide better image based diagnosis of RoP for a brighter young generation.

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