Novel Hybrid Bio-medical Image Processing Algorithms for the Detection of Glaucoma Disease in Human Eyes using AI-ML and Real Time Embedded System

Tian Jipeng
Computer Science College, Zhongyuan University of Technology, China

Hou Lingmei
Dos in Computer Science, University of Mysore, India

G. Hemantha Kumar
Dos in Computer Science, University of Mysore, India

ABSTRACT
Glaucoma is the second largest disease in the world after cancer (different types) & is a silent thief/killer of sight which is characterized by the increase in the intraocular pressure with slow vision loss leading to permanent blindness. Although the disease is incurable, but its symptoms can be minimized-therefore early detection of the disease is essential. It is a very expensive process to detect the disease using the modern tools as a result of which we are developing some sort of novel methodologies for the detection process (using off line methods) such that it is affordable by all the sections of the society, also it can be detected at the early stage and prevention can be taken after follow ups. The Artificial Intelligence (AI) & Machine Learning (ML) concepts are going to be used in the detection process by developing hybrid algorithms. Various types of glaucoma exist, for example, primary, secondary & the higher order ones. Hybrid algos could be developed and used for detection purposes with more efficiency compared to the works done till date. The software tools such as MATLAB, Xilinx, Modalism, LabVIEW, Kiel, HDL, could be planned to be used for the simulation purposes for the disease detection process. The work done in the simulation stage could be evaluated or validated using a real time embedded system or by the usage of some interfacing hardware of a suitable type, which may be a DSP based TMS board or a FPGA kit or a Micro-controller Kit or a Raspberry Pi or it can be any new interfacing device.

Keywords
Glaucoma, CDR, IOP, Simulation, Neural Network, SVM, RNFL

1. INTRODUCTION
In this introductory section, a brief review of the concepts relating to the glaucoma disease, its types, how it can be detected. Glaucoma damages the optic nerve which leads to permanent blindness. It cannot be cured, so detecting the disease in time is very important. Glaucoma is one of the most severe eye diseases according to the number of blindness causes in India and western countries and is one of the top 10 leading diseases in the world. Therefore, the early detection, long-term monitoring of the patients and the decision about the appropriate therapy at the correct time are the serious tasks for any ophthalmologist. This earlier detection of deadly eye disease has been proposed by many using advanced image processing analysis & recognition techniques till date, which are presented in this research work. This state of art techniques which had already been assisting the doctors in various fields such as earlier detection and diagnosis of diseases, clinical decisions, remote sensing surgeries and so forth are also dealt with here in this context. In short to say, glaucoma is a chronic eye disease in which optic nerve is progressively damaged & slowly starts to cause sight loss.

An anatomy of human eye is approximately a spherical organ. The protective outer layer of the eye is called the sclera. The other components of the eye are regions such as cornea, lens, iris, and the retina. The retina is the light-sensitive tissue that lines the inside of the eye. The optical elements within the eye focus an image onto the retina of the eye, initiating a series of chemical and electrical events within the retina. Nerve fibers within the retina send electrical signals to the brain, which then interprets these signals as visual images. Retina is approximately 0.5 mm thick and covers the inner side at the back of the eye. The center of the retina is the optical disc, a circular to oval white area measuring about 3 mm2 (about 1/30 of retina area).

2. MODERN GLAUCOMA DIAGNOSIS METHODS
Currently, many modern techniques have been developed across the world in various hospitals to detect the glaucoma by using HRT, OCT, which makes use of the cup – disc ratio of the blind spot in the human eye (back end of the human eye). ONH is one of the advanced methods which can be used to detect the early stages of glaucoma, but this ONH procedure needs trained specialist doctors & technicians to operate the device

Specialized costly equipment like (Optical coherence tomography) OCT & (Heidelberg Retinal Tomography) HRT systems. But, assessment of the OD by an eye surgeon is subjective & caters to the availability of the HRT / OCT device, which turns out to be a costly process which may tax the glaucoma patients. Fundus camera captures the 2D fundus digital image of the affected eye, which also photographs the retinal surface area of the human eye. This fundus camera is an advanced high-power microscope which is attached with a camera and takes the photo (digital image) of the internal surface, i.e., rear part of the human eye. This captured digital image includes the retinal vasculature, OD, posterior pole, OC & the macula, further this digitized image can be processed for the glaucoma detection. Apart from fundus cameras, other devices such as Spaide Auto Fluorescence Filters could also be used for capturing the fundus images, but is quite expensive than the former.

When compared with the HRT / OCT scanning machines, the digital fundus camera is less expensive and also much easy to operate even by a technician, thus able to fetch multiple scans or images of the affected eyes. A large number of researchers have been using the fundus images captured by the digital

fundus camera in order to analyze the OD & OC structures. Few dis-advantages/drawbacks exists in this modern glaucoma diagnosis & detection approach. Some of them are the requirement of trained technicians or doctors for operating the eye scanning machines or the glaucoma detection equipment. The cost involved is also very high, which is not a feasible parameter & affordable by the rural, poorer sections of the society.

Though the modern glaucoma detection techniques can lower the intraocular pressure using a surgery called as trabeculectomy, the same suffers from couple of drawbacks like inconvenience of applying eye drops to the human eye every day, thus suffering from the side effects of burning, inflammation, pain, swelling. This has been proved by many clinical trials in different hospitals also. Medical co-morbidities like hypertension, diabetes & heart disease occurs in a majority of the glaucoma patients who are in the final stages. Hence, in contrary to these modern glaucoma detection techniques, some alternate methods could be thought of & such low-cost methods are being proposed in our research work.

3. PROPOSED GLAUCOMA DIAGNOSIS METHODS

3.1 Comparison of Conventional Methods

As the conventional methods & the modern glaucoma diagnosis & detection methods suffer from certain lacunas, we have identified those lacunas and we are going to develop cost-effective eye disease detection methods for the humans who are affected with glaucoma disease using software techniques by using different methodologies. These are described in brief in the future sections along with their proposed block-diagrams & flow-charts. The proposed works can serve a good contribution in overcoming the drawbacks in the conventional methods of detection, so that the direct supervision of the skilled professionals can be reduced to maximum extent and the overall process will become cost-effective.

3.2 Proposed Methodology

The proposed methodology that may be used in our research work is presented in this section (may change in due course as the research progresses due to the development of new innovative techniques, ideas & concepts). This proposed methodology that may be adopted in this context of the research work is depicted in the Figure 1 in a very highly abstracted manner with various blocks in the vertical & horizontal fashion.

The hardware is DM3730 SOC based low-cost low power single board computer system & the block diagram of the hardware is presented in the Fig. 1. DM3730 is a multi-core processor that consists of ARM cortex A8 and a TMS320DMC64X+ Digital Signal Processor (DSP). The single board system (Beagle board) has many extensible interfaces for the implementation of detection of retinal diseases. An LCD of 4.7 inch in size with (800 × 400) resolution. Micro SD of 4 GB and the high-speed USB hub are used for display, data storage and for external input-output devices. The source images are acquired from the fundus scope interfaced to one of the USB ports. The database as well as the application programs resides in SD card memory. The flow block diagram is shown as figure 2.

The proposed algorithm can be developed for the detection of glaucoma using the areas of cup and disc, which can be used for the assessment of glaucoma. The flow block diagram is shown as fig 3. Finally, the algorithm could be initiallyimplemented on LabVIEW platform. Finally, these C programs could be replaced with Open CV programs as the single board computer system operates on open-source Linux platform & observing the experimental results. Finally, theresult could be obtained and can be presented in the final stage, which would conclude the effectiveness of proposed methodology that is going to be developed by us.

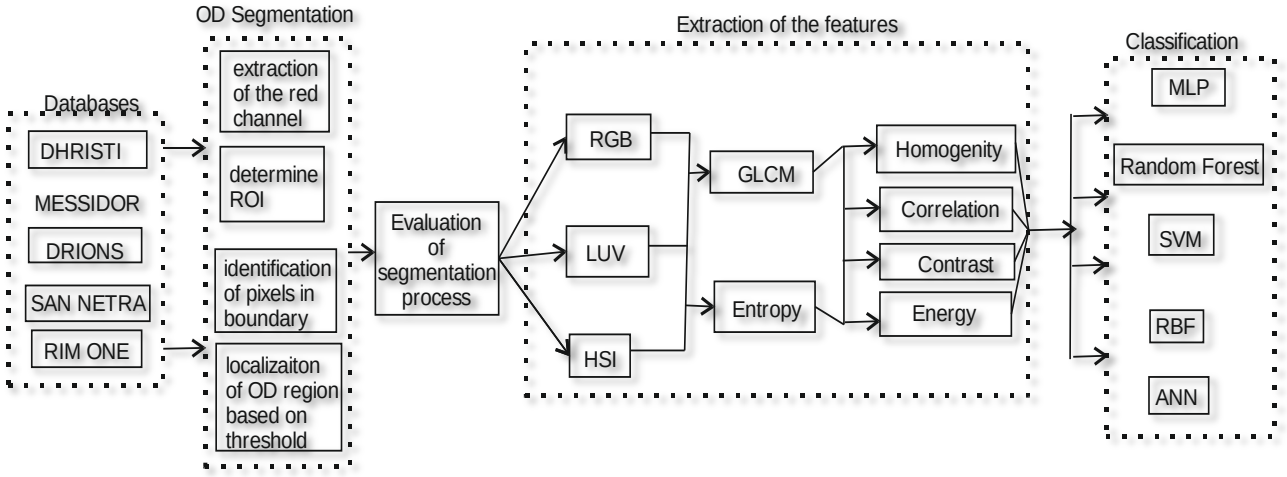

Fig 1: Block diagram of the proposed software methodology that could be adopted – 1

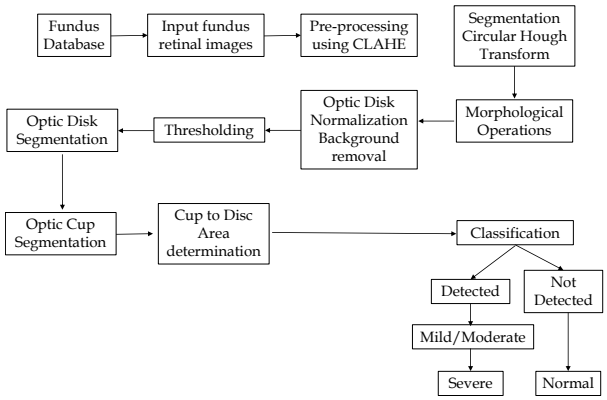

Fig 2: Block diagram of the proposed software methodology that could be adopted – 2

Because of glaucoma presence in the eyes, the optic cup size gets increased and the optic cup to optic disk ratio (CDR) increases. This research project proposal proposes glaucoma disease detection from retinal fundus images using AI/ML approach as the classifiers, feature detectors, pre-processors, enhancers, segmentations, etc. Hence, FPGA is better choice for the neural networks instead of DSP or ASIC implementation.

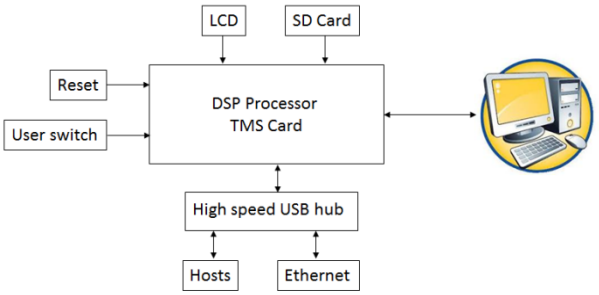

Fig 3:Block-diagram of proposed h/w implementation methodology using DSP processo

3.3 Proposed methods of analysis of data

The proposed methods of the analysis of data may be achieved using the following steps and is shown in the Fig. 11 with the following analysis carried out.

- Collecting images of human eyes (Both healthy and unhealthy) using appropriate image capturing devices ….. an large number of samples (data base / data set of image collection) from various sources from hospitals & on-line image databases.
- Preparation of our own desired image fundus data base using state-of-art techniques.
- Use of filtering & transformation techniques to get a fine image.
- Performing image pre-processing (noise removal, gray scale conversion, segmentation, enhancement), processing and analysis with the use of mathematically developed equations in spatial & frequency domains.
- Finding the ROI using different IP techniques.
- Finding the features of the extracted image using feature extraction techniques.
- Developing algos to detect the glaucoma eye disease in human eyes by using 3 different concepts based on AI & ML approaches, viz., Fuzzy, ANN & the CNN methods.
- Simulating the same using Matlab/LabVIEW or any type of software.
- Developing .m code (or any other platform) for the process in the previous steps, observing the results, tabulation of the results obtained and determining the severity of the patient.
- Comparision of all the developed methodologies for the best performance.
- Implementation using real time hardware interfacing kits using embedded system approach.

4. NATURE OF THE DATA

The nature of the data that is being required for the detection of the chronic eye disease is the fundus images of the patients, which is 2 dimensional in nature.

- It is to be noted that the fundus images are taken from the fundus cameras that are being used in the hospitals to capture the image of the eye and is a high-resolution camera which takes the pic of the eye up to millions of zoom level.
- This fundus pic is a 2D image (coloured) and is the data which is given as input to the algorithm for the disease detection process.
- The nature of the data is an image I (x, y), which is a 2D information, consisting of x & y coordinates of the pixels in the captured image.

The hardware kits that are going to be used for the research work is DSP card with CCS-Code Composer Studio & the National Instruments Kits / FPGA Spartan kits for the experimentation purposes / Xilinx Spartan Kits or any other hardware interfacing platform or it may be raspberry pi, microcontroller kits, zed boards. The software tool that is used for the research work is MATLAB with Simulink modelling for simulation purposes & the Image Processing tool box or LabVIEW with NI software or VHDL language. The embedded software could also consist of the following. The single board computer system operates on open-source Linux platform. Hence, the algorithms developed are implemented with open CV libraries. Kiel software, world's leading developer of embedded systems software, makes macro assemblers, real time kernels, debuggers, simulators, etc. can also be used as it is a powerful software tool for the most demanding embedded applications in the health sectors. It has been thought of developing the hybrid algorithms using the MATLAB 19 version as it has got a number of built-in tool boxes such as the neural network tool box, signal processing tool box, image processing tool box, optimization tool box & the Simulink modules also.

For proposals involving human participants or animal participants mention all procedures required to ensure confidentiality of participants, benefits and risks, data privacy and protection method.Human participants are involved only for the collection of the fundus images of the eyes from the patients using the fundus cameras in the hospitals area.

In other sense, the fundus camera can also be taken to a medical camp where glaucoma affected patients will assemble and their images can be taken.The patient will have to sit in front of the fundus camera, just like how the eye sight is checked for the powers & the images will be captured and stored, all the images can be stored as patient's medical records, which can be used for analysis purposes.The data collected by the hospital authorities has to be kept confidential as it is involving the biometric information also of the human beings & can be taken for research purposes only after proper letter of correspondences and permissions.

5. EXPECTED RESULTS

The expected results of this proposed research is the detection of eye affected with glaucoma using state of art of image technologies using AI & ML concepts, i.e., software implementation and secondly, with the hardware implementation using FPGA / DSP / SPARTAN / VHDL / XILINX kits (any 2-3 implementation, to be decided in due course). This is one of the approaches where very less human interaction giving rise to highly hygienic process & making the system identification fully automatic. The expected results of the chosen research work could be summarized as follow.

- Glaucoma can be detected using transformation techniques using diff. types of hybrid algorithms using AI & ML techniques.
- Observation of the hardware experimental results for validation purposes.
- Development of an android app for glaucoma detection (if time permits).

6. REFERENCES

[1] Spector, A. Z. 1989. Achieving application requirements. In Distributed Systems, S. Mullender V. Krishna Sree& P. Sudhakar Rao, "Hardware implementation of enhancement of retinal fundus image using Simulink", IEEE Asia Pacific Conference on Postgraduate Research in Microelectronics and Electronics (Prime Asia), pp. 239 - 244, DOI: 10.1109/PrimeAsia.2013.6731213, 2013.

[2] S. Sekhar, W. Al-Nuaimy and A.K. Nandi, "Automated localization of retinal optic disk using hough transform", 5th IEEE Int. Symposium on Biomedical Imaging: From Nano to Macro, pp. 1577 – 1580, 2008.

[3] S. Sekhar, "Automated localisation of retinal optic disk using hough transform", Department of Electrical Engineering and Electronics Engg., University of Liverpool, UK

[4] MahdadEsmaeili, Hosseinrabbani and AlirezaMehridehnavi, "Automatic optic disk boundary extraction by the use of curve let transform and deformable variation level set model", Pattern Recognition, Vol. 45, pp. 2832–2842, 2012.

[5] MahdadEsmaeili, HosseinRabbani and AlirezaMehridehnavi, "Automatic optic disk boundary extraction by the use of curve let transform and deformable variation level set model", Elsevier Science Direct's Pattern Recognition, Vol. 45, No. 7, pp. 2832–2842, Jul. 2012.

[6] Rudiger Bock, Jorg Meier, Laszlo G. Nyul, Joachim Hornegger, Georg Michelson, "Glaucoma risk index : Automated glaucoma detection from color fundus images" Medical Image Analysis, Vol. 14, No. 3, pp. 471-481, Jun. 2010.

[7] R. Chrastek , M. Wolf , K. Donath, H. Niemann, D. Paulus, T. Hothorn, B. Lausen, R. Lammer, C.Y. Mardin, G. Michelson, "Automated Segmentation of The Optic Nerve Head For Diagnosis Of Glaucoma", Medical Image Analysis, Vol. 9, No. 4, pp. 297–314, Aug. 2005.

[8] GopalDatt, JayanthiSivaswamy, S.R. Krishnadas, "Optic Disc and Cup segmentation from Monocular Color Retinal Images for Glaucoma Assessment", IEEE Trans. on Medical Imaging, Vol. 30, Issue 6, pp. 1192 – 1205, 14 Jun. 2011.

[9] JayanthiSivaswamy, S.R. Krishnadas, GopalDutt Joshi, Madhulika Jain, Ujjwal, Syed Tabish A., "Drishti-GS retinal image dataset for optic nerve head (ONH) Segmentation", 11th IEEE Int. Symp. on Biomedical Imaging (ISBI), Beijing, China, pp. 53 – 56, 29 April 2 - May 2014.

[10] Siddalingaswamy P.C., GopalakrishnaPrabhu K., "Automatic Localization and Boundary Detection of Optic Disc Using Implicit Active Contours", Int. Jour. of Comp. Applications (IJCA), ISSN 0975 – 8887, Vol. 1, No. 7, pp. 1-5, 2010.

[11] MeindertNiemeijer, Michael D. Abramoff, Bram Van Ginneken, "Fast Detection of the Optic Disc and Fovea in Colour fundus photographs", Med Image Anal., Vol. 13, No. 6, pp. 859–870, Dec. 2009.

[12] Md. Saleh Miri, Michael D. Abràmoff, Kyungmoo Lee, MeindertNiemeijer, Jui-Kai Wang, Young H. Kwon, Mona K. Garvin, "Multimodal Segmentation of Optic Disc and Cup from SD-OCT & Color Fundus Photographs Using a M/c-Learning Graph-Based Approach," IEEE Trans. on Med. Imag., Vol. 34, Issue 9, pp. 1854 – 1866, Sep. 2015.

[13] Jaeyoung Kim, Heesung Jun, "Implementation of Image Processing and Augmented Reality Programs for Smart Mobile Device", 6th International Forum on Strategic Technology (IFOST) 2011, pp. 1070-1073

[14] A. Sopharak, B. Uyyanonvara, S. Barman and T.H. Williamson, "Automatic detection of diabetic retinopathy exudates from non-dilated retinal images using mathematical morphology methods", Computerized Medical Imaging and Graphics, Vol. 32, pp. 720–727, 2009.

[15] Rashid Jalal Qureshi et.al., "Combining algorithms for automatic detection of optic disc and macula in fundus images", Computer Vision and Image Understanding, Vol. 116, pp. 138–145, 2012.

[16] Aby P.K., Anumol Jose, Bibin Jose, Dinu L.D., Jomon John, Sabarinath G, "Implementation and Optimization of Embedded Face Detection System", International Conference on Signal Processing, Communication, Computing and Networking Technologies (ICSCCN 2011), pp. 250-253, 2011.

[17] Shifeng Hu, Zuhua Fang, Jie Tang, HongbingXu, "Research of Driver Eye Features Detection Algorithm Based on OpenCV", Second WRI Global Congress Intelligent Systems (GCIS), Vol. 3, pp. 348 – 351, 2010.

[18] SIvanCuljak, David Abram, TomislavPribanic, HrvojeDzapo, Mario CifrekA, "Brief introduction to OpenCV- MIPRO", Proceedings of the 35th International Convention, pp. 1725 – 1730, 21-25 May 2012.

[19] SlavomirMatuska, Robert Hudec and MiroslavBenco, "The Comparison of CPU Time Consumption for Image Processing Algorithm in Matlab and OpenCV", ELEKTRO, pp. 75 – 78, 21-22 May 2012.