Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 25 (2016) 12 – 19

Procedia Technology

Global Colloquium in Recent Advancement and Effectual Researches in Engineering, Science and Technology (RAEREST 2016)

Segmentation of 2D and 3D Images of Carotid Artery on Unified Technology Learning Platform

R.Hemalatha[a*], N.Santhiyakumari[a], M.Madheswaran[b], S. Suresh[c]

[a] *Department of Electronics and Communication Engineering, Knowledge Institute of Technology, Salem-637504, Tamilnadu, India.*
[c] *Mahendra Engineering College, Namakkal-637503, Tamilnadu, India.*
[d] *Mediscan systems, Chennai, Tamilnadu, India.*

Abstract

In the decade of technological advancement, the image processing technique has made it possible to save lives of several beings. The image segmentation technique is used to eliminate the complex procedures in the analysis of blood vessels for cardiovascular diagnosis. The objective of this paper is to compare the segmented intima-media interface of 2D and 3D carotid artery images and implement in Unified Technology Learning Platform. The intima-media interface has been extracted using threshold segmentation technique for both 2D and 3D images. The pre-processing of the carotid artery and speckle removing followed by morphological technique can be used in the developed segmentation algorithm with the aid of Aphelion Dev software. The segmented results of 2D and 3D carotid artery image have been implemented in Unified Technology Learning Platform which enhances the speed of processing an image as 120ns. This technique will helps to improve the appearance of ultrasound image and detects the presence of abnormalities in carotid artery earlier during the diagnosis.

Peer-review under responsibility of the organizing committee of RAEREST 2016

*Keywords:*Common carotid artery (CCA); Unified Technology Learning Platform; Intima-media layer; Threshold segmentation technique; Aphelion Dev.

**E-mail address:* hemarcha@gmail.com

Peer-review under responsibility of the organizing committee of RAEREST 2016
doi:10.1016/j.protcy.2016.08.075

1. Introduction

Cardio Vascular Diseases (CVDs) are the number one cause of death globally, more people die annually from CVDs than from any other cause. An estimated 17.3 million people died from CVDs, representing 30% of all global deaths by World Health Organization (WHO) [22].The main heralds of CVD are smoking, obesity, hypertension and a disturbed serum lipid profile. The therapy evaluation and clinical data analysis are important to the cerebrovascular and cardiovascular abnormalities diagnosis. Measurement accuracy and geometric understanding of common carotid artery (CCA) play an important role in carotid atherosclerosis assessment and management, which requires accurate segmentation.

Conventional 2-D ultrasound has used in the assessment of plaque morphology. However, due to insufficient image contrast and to the variability of conventional 2-D ultrasound exams, accurate assessments of morphological plaque changes are difficult such as volume and surface irregularity. Because it is difficult to reposition the 2-D image of the plaque, monitoring the changes in the development of the plaque over long periods of time using conventional 2-D ultrasound is problematic. In addition, the reconstruction of a 3-D impression of the vascular anatomy and the plaque using multiple 2-D images is time consuming and prone to variability and inaccuracy.

Three-dimensional (3D) ultrasound is used to improve the visualization and quantification of complex anatomy and pathology to monitor the progression of atherosclerosis. Non-invasive and reproducible 3-D imaging techniques that allow for the direct visualization and quantification of plaque development are becoming more important in serial monitoring of disease progression and deterioration. The characterization of carotid plaques in three dimensions will potentially improve investigations into the changes of surface morphology, plaque geometry, and plaque distribution and these can provide important information about the effects of anti-atherosclerotic therapies.

The classical image segmentation techniques uses the information regarding texture, shape, contours, etc., perform well when the images are simple, less noisy. However, in the domain of medical images, it is found that the objective function is usually much complex. Thus, application of several classical techniques becomes limited. Bastida-Jumilla M.C.et al. [1], suggested the segmentation method which is used to measure the IMT by using anisotropic diffusion or geodesic active contours. Chan, R.C. et al [2], developed a new method for B-mode ultrasound image processing that uses all available image data for anisotropic noise suppression. It is currently being extended to 3D carotid image data as well as to RF ultrasound data.

Dana E. ilea [4], developed a fully automated segmentation method for common carotid artery which has an automatic threshold technique to detect the region of interest and Gaussian filtering scheme in order to remove the speckles and artifacts from the ultrasound image. Faita, F. et al [5], developed a method to evaluate the Intima-media thickness based on the First Order Absolute Moment and the result has compared using regression analysis and Bland Altman analysis. An automated technique for the carotid segmentation based on Hough Transform has been developed by Golemati et al [6]. It is used to identify the CCA in both longitudinal and transverse images without user intervention. But it can identify only the horizontal and vertical vessels. However, B-mode ultrasound images consist of curved and inclined CCA.

Ilea et al. [7], described a Computer Aided Detection (CAD) algorithm that is able to segment and measure the IMT in ultrasound carotid images. It is a fully automated technique and used to identify the two interfaces of IMT without any user intervention. Here the segmentation is based on spatially continuous vascular model. The different generation of segmentation methods and the software used for medical image segmentation has been described by Koles1, Z.J. [8]. In order to reduce the manual tracing problem in segmentation, various technique have been described to perform automated Intima-media segmentation such as a multiscale dynamic programming developed by Liang Q. et al. [9] it requires retraining whenever the change takes place in the characteristics of image.

The snakes segmentation technique developed by Loizou C.P.et al.[10] also used for detecting intimal layer of the far wall of the CCA in longitudinal images. However, it requires manual interruption to select the region of interest.Maulik, U. [11], described the detailed survey of the applications of genetic algorithms (GA) in medical image segmentation. The selection of the different genetic operators as well as the termination criteria are important issues in GAs. Often, these are tuned manually, and require a large amount of expertise as well as experience.

Molinari, F. et al [12], described a completely automated layer extraction technique for the segmentation named as CALEXia which is an integrated approach that used to extracting the carotid adventitial walls. There are several segmentation method used for diagnosing ultrasound carotid artery images which are used in both fully automatic and semi-automatic manners [14-16]. Selzer, H.et al [17], developed the computerized edge-tracking multi frame technique that automatically determine the arterial diameter and highly reproducible. In case of semi-automated method there is a need of manual intervention which causes error in measurement.

Stanley Osher et al. [19], suggested the segmentation methods which contains television regularized energies. For the mean curvature motion problem, the Split Bregman approach is found to be more efficient than other methods, including techniques based on graph-cuts. In addition to its speed, the Split Bregman approach has the advantage that it can solve isotropic segmentation problems, and does not require any regularization. Recently, FPGA technology is used in the implementation of algorithms for image processing. Chetan, S. [3], developed a real time hardware for image segmentation with resource optimized adaptive median filter (AMF). The edge can be detected using sobel operator and the resource utilization of segmentation is 50% less compared to the AMF.

The implementation of image processing algorithm in dedicated hardware create several advantages particularly in terms of resource, power consumption, quality of the results and costs. Ratnayake, K. et al.[13], developed a robust real-time, scalable and modular Field Programmable Gate Array based implementation of a spatiotemporal segmentation of video objects. The hardware implementation achieved an optimum processing speed of 133 MPixels/s while utilizing minimal hardware resources.

Roy Cardinal .M.H et al. developed a new three dimensional (3-D) intravascular ultrasound segmentation technique based on the fast-marching method and uses gray level probability density functions (PDFs) of the vessel wall structures. The gray level distribution of entire intravascular ultrasound pullback was modelled with a mixture of Rayleigh PDFs. The multiple interface fast-marching segmentation has been used to compute the lumen, intima plus plaque structure, and media layers of the vessel wall simultaneously.

In this paper, the contribution has been made to implement the segmentation of 2D and 3D ultrasound carotid artery image using Aphelion Dev real time software with a dedicated hardware. The segmented intima-media interface of abnormal CCA image using threshold method has been implemented in Unified Technology Learning Platform kit which increases the speed of processing an image. The implementation of image processing algorithm in dedicated hardware creates several advantages particularly in terms of resource, speed, power consumption and costs. The main aim of this paper is to implement the segmented image in hardware which offers the minimum resource utilization and modifications to the algorithm are made if needed, so that it provides reconfigurable aspect.

2. Methodology

2.1. Image Acquisition

The ultrasound scanner with the broadband compact linear array transducer has been used for the data acquisition of the image. In order to obtain the similar images, the transducer has placed at the beginning of the bifurcation of common carotid artery (CCA). The obtained images have been stored in a PC for further processing.

2.2. Enhancement Technique

The ultrasound image has the problem of low contrast between the anatomical structures due to low echo responses of ultrasound. It results that the subjects are not easily distinguishable. In order to get better and meaningful segmentation need to improve the quality of images. The Histogram Equalization method [14] has been used to improve the appearance of the CCA image without affecting the structure.

2.3. Detection of Region of Interest (ROI)

The ROI defines the portion of the image where the Intima-media is located. The area situated above and below the interface that separates the blood and the tissue of the vessel has been considered as region of interest. Parameters concern to the lumen and the Intima-media considered to identifying ROI correctly. A semi-automated technique has been used to detect the ROI which requires manual intervention to discover the far wall of the CCA.

2.4. Pre-Filtering Method

The identified image region has been pre-filtered before applying the threshold technique. This step is used to attenuate speckle noise which presents in the ultrasound image without disturbing any important features of the image. The Gaussian filtering technique [4] has been used in the removal of speckles. It results the smoothed image of common carotid artery far wall. The filtering has been performed based on a convolution using a kernel size of 3 and the standard deviation (σ) of 0.75.

The steps in processing of developed technique as shown in Fig.1.

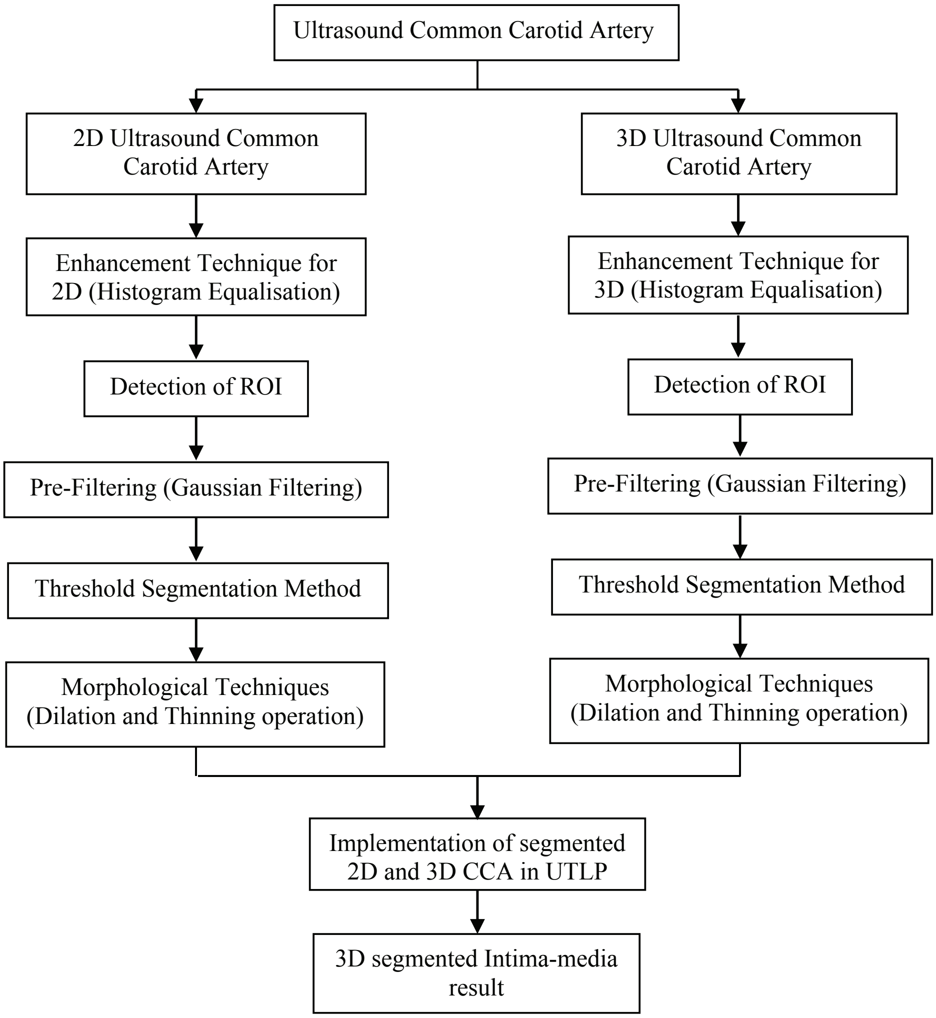


Fig.1. Steps in processing with the hardware implementation

2.5. Threshold Technique

The thresholding algorithm is applied to detect the borders between the two main image classes such as the lumen and the carotid artery tissues. Here each individual pixel has been set to 1with a value between a lower and upper bound otherwise set to 0. The thresholds are inclusive, so the output value is,

$$\begin{aligned}&\textit{If}\left(in\,\mathrm{Im}(i,j)\geq loThresh\ \&\ \&in\,\mathrm{Im}(i,j)\leq hiThresh\right)\\&\text{then}\ out\,\mathrm{Im}(i,j)=1\quad(1)\\&\text{else}\ out\,\mathrm{Im}(i,j)=0\end{aligned}$$

The output image is a binary image, with values 0 and 1. The lower and upper bound range has been set as 85 and 120 respectively which extract the lumen-intima interface.

2.6. Morphological Operations

Dilation

Dilation of image is a basic operation of mathematical morphology. It uses horizontal structure element for probing and expanding the shapes contained in the threshold image to provide continuity between the pixels of lumen-intima interface. The number of iteration and the size of structuring element have to be set as 4 in order to obtain continuity.

Thin Method

This method is used to perform a thinning of the input binary or grey scale image. The neighborhood LUT defines the neighborhood configurations in which a pixel should be erased. It has decreased in the case of a gray scale image. Homotopic pruning is considered as a predefined neighborhood LUT to attain the accurate intima-media. Here steps specify the number of times that the thinning should be applied and 4-connected graph has been applied for thinning operation.

2.7. Implemented in UTLP kit

Unified Technology Learning Platform (UTLP) is an integrated learning environment consisting of hardware and software tools as shown in fig.2. The features of UTLP are TI OMAP 3530 SOC with ARM Cortex A8 600MHz CPU, DM64X with 430MHz DSP processor, Xilinx Spartan-6 LX25T FPGA, 128MB CPU RAM –mDDR and 64MB FPGA RAM-DDR2, 128MB NAND FLASH, Video OUT-VGA, LCD-local/external , Audio Video Support & TV Out, Video IN-Camera, Audio in, audio out, stereo out, Boot Loader, Xloader, Uboot Operating Systems, Linux X11 (Graphics), Eclipse IDE & XILINX ISE Web Pack, Stub Application & ULK Control panel.

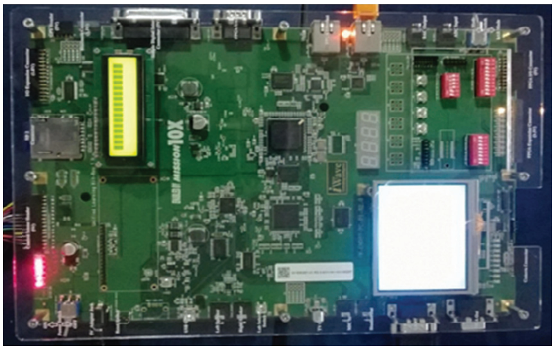


Fig.2. Unified Technology Learning Platform (UTLP) kit

The ARM-8 Cortex processor, based on the ARMv7 architecture, has the ability to scale in speed from 600MHz to greater than 1GHz. The Cortex-A8 processor can meet the requirements for power-optimized mobile devices needing operation in less than 300mW.

The resulting image has been implemented in Unified Technology Learning Platform kit which consists of 320 x 240 Graphical Liquid Crystal Display (GLCD). An image can be displayed on GLCD with the help of Application Programming Interface (API) which is coded using Eclipse software.

3. Results and Discussion

The 2D image of common carotid artery has obtained from ultrasound scanner and the 3D CCA image has constructed using MATLAB R2012aversion and the steps in processing of developed technique which explained in the previous section has been applied. The longitudinal section acquired 2D and 3D input image as shown in fig.3a and fig.4a. Fig.3b and fig.4b shows the pre-processed images, it is used to enhance the contrast of input images. The lumen has low intensity pixels surrounded by higher intensity pixels of carotid wall layers such as Intima-media which has identified as ROI for both 2D and 3D ultrasound images as shown in fig.3c and fig.4c. The Gaussian filtered (Pre-filtered) ROI image as shown in fig.3d and fig.4d with the size of 3. It is used to remove the speckles which present in image region due to low echoes of US scanner. Fig.3e and fig.4e shows the threshold segmented image with threshold value varying from 85 to 120 which impart the lumen-intima interface of 2D and 3D carotid image. The resulting image from previous step has much discontinuity. In order to reduce these troubles the morphological techniques such as dilation and thinning operation are used to extend the horizontal structure elements of the intima –media interface as shown in fig.3f and fig.4f.

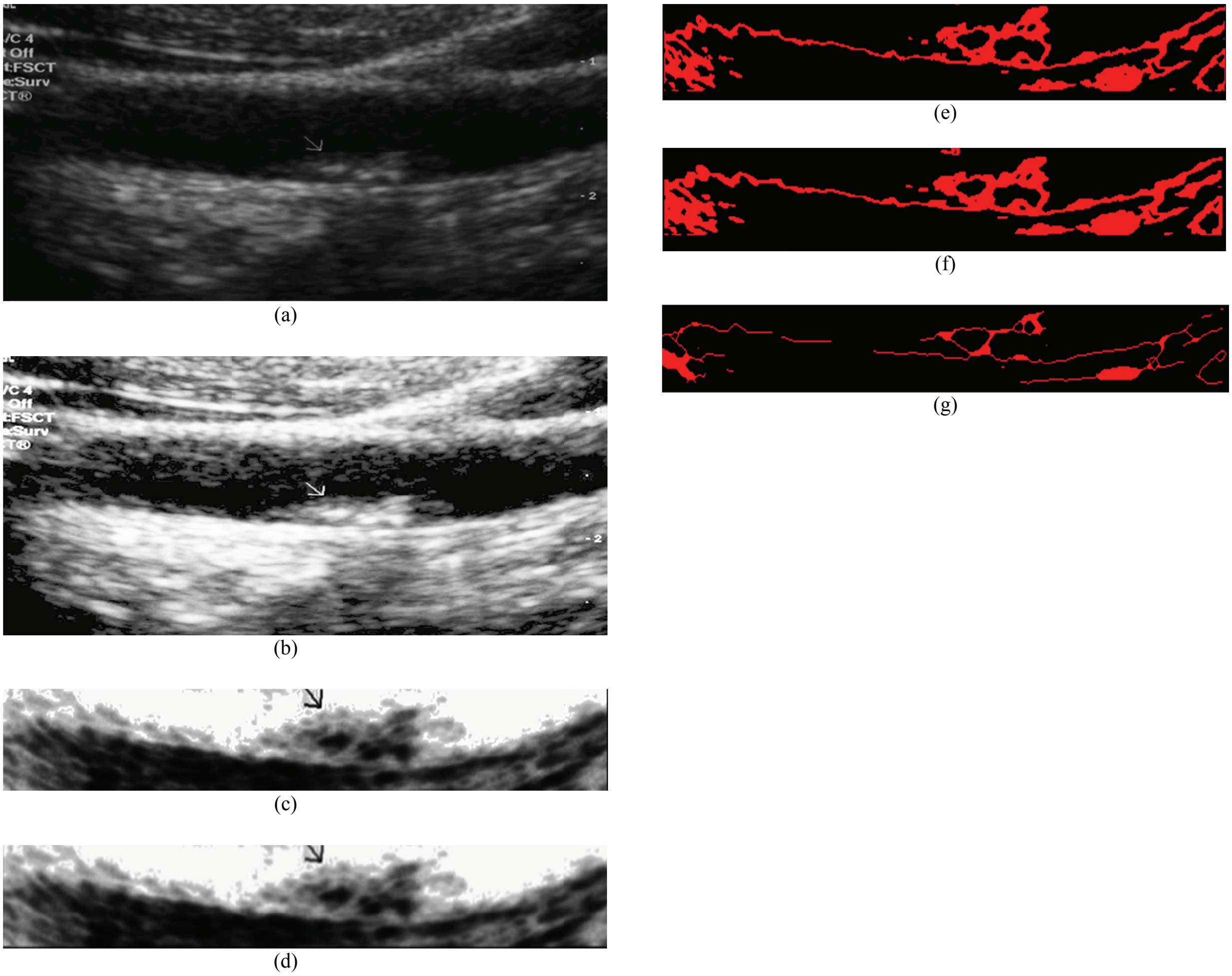
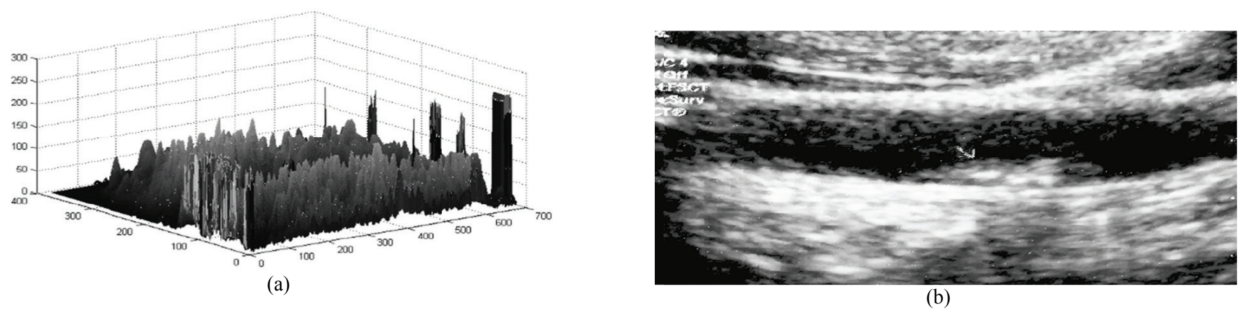


Fig.3.a. 2D Input CCA Image. b. Pre-Processing Image. c. ROI Detection. d. ROI Pre-Filtering image. e. Threshold segmented image. f. Dilating image. g. Segmented output image.



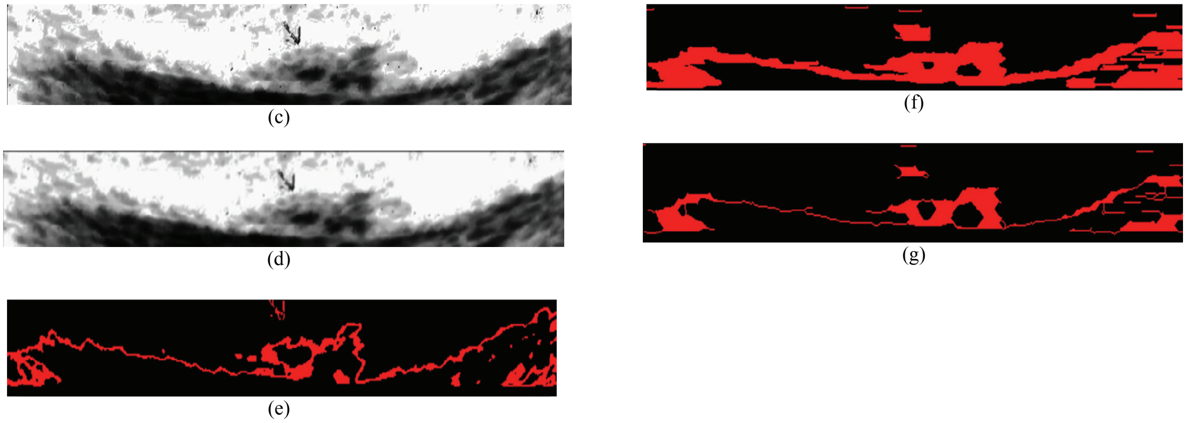


Fig.4.a. 3D Input CCA Image. b. Pre-Processing Image. c. ROI Detection. d. ROI Pre-Filtering image. e. Threshold segmented image. f. Dilating image. g. Segmented output image.

The resulting image of post-processing is shown in fig.3g, which improves the result of dilated image. Finally the morphological thin operation has been performed.

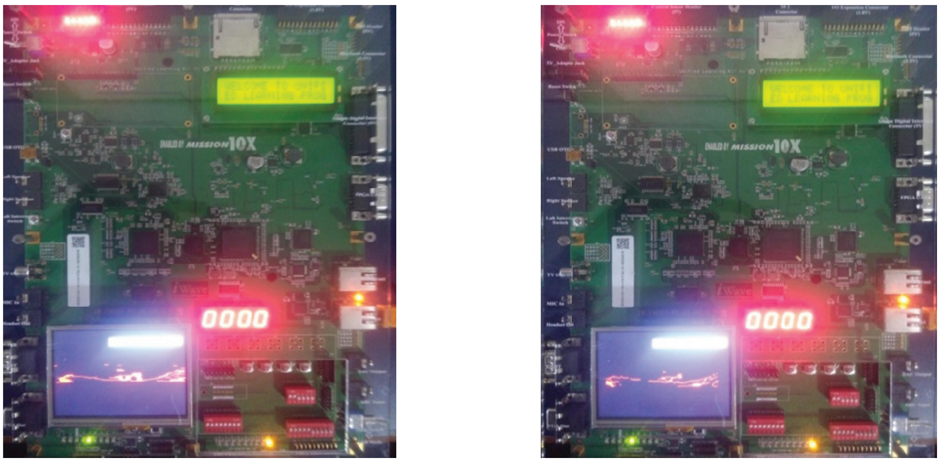


Fig.5. Result from CLCD of UTLP kit

The obtained results from Aphelion Dev software have been implemented in Unified Technology Learning platform. It utilized minimum hardware resources for implementing the segmented intima-media layer. It takes the processing speed for 2D CCA segmented result as 60ns and for 3D CCA segmented result as 120ns.

4. Conclusion

The segmentation of 2D and 3D ultrasound carotid artery image with the identified region has been implemented in Unified Technology Learning Platform hardware. The speckles in the ultrasoundcarotid artery image have been removed by Gaussian filtering which results the noiseless ultrasound image. The lumen-Intima interface has been extracted with the help of threshold technique. The segmentation of 2D and 3D carotid artery image has been obtained using Aphelion Dev real time software. It is used to reduce the complexity of hardware implementation with the minimum hardware resources and low power consumption. The hardware implementation of 2D segmented result provides much discontinuity than 3D segmented result. The segmented image has been desirable for employ in real time medical applications to examine the presence of abnormalities earlier.

Acknowledgment

This work is supported by All India Council for Technical Education under Research Promotion Scheme for Cardio and Cerebro vascular disease analysis and we are grateful to Mediscan Systems, Chennai for providing images for our analysis.

References

[1] Bastida-Jumilla, M.C. Morales-Sanchez, J. Verdu-Monedero, R. Larrey-Ruiz, J. and Sancho-Gomez, J.L. (2010) 'Detection of the intima and media walls of the carotid artery with geodesic active contours', in IEEE Proc. 17th Int. Conf. Image Processing, pp. 2213 -2216.

[2] Chan, R.C. Kaufhold, J. Hemphill, L.C. Lees, R.S. and Karl, W.C. (2000) 'Anisotropic edge- preserving smoothing in carotid B-mode ultrasound for improved segmentation and intima media thickness (IMT) measurement', Comput. Cardiol., vol. 27, pp. 37–40.

[3] Chetan, S.Deokar and Baru, V. B., (2011) 'VLSI Implementation of Image Segmentation with Resource Optimized Adaptive Median Filter', International Conference on VLSI, Communication & Instrumentation, pp. 14-18.

[4] Dana E. ilea, Caoimhe Duffy. Liam Kavanagh,Alice Stanton and Paul F. Whelan, (2013) 'Fully Automated Segmentation and Tracking of Intima Media Thickness in Ultrasound Video Sequences of the carotid artery', IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 60, no. 1, pp. 158-176.

[5] Faita, F. Gemignani, V. Bianchini, E. Giannarelli, C. and Demi, M. (2006) 'Real-time measurement system for the evaluation of the intima media thickness with a new edge detector', in Proc. 28th Annu. Int. Conf. IEEE Eng. Med. Biol. Soc., pp. 715–718.

[6] Golemati, S. Stoitsis, J. Sifakis, E.G. Balkizas, T. and Nikita, K.S. (2007) 'Using the Hough transform to segment ultrasound images of longitudinal and transverse sections of the carotid artery', Ultrasound Med. Biol., vol. 33, no.12, pp.1918–1932.

[7] Ilea, D.E. Whelan, P. F. Brown, C. and Stanton, A. (2009) 'An automatic 2D CAD algorithm for the segmentation of the IMT in ultrasound carotid artery images', in Proc. 31st Annu. Int. Conf. IEEE Eng. Med. Biol. Soc.: Engineering the Future of Biomedicine, pp.515–519.

[8] Koles1,Z.J. and Withey,D.J. (2007), 'Medical Image Segmentation: Methods and Software'IEEE Trans. on NFSI & ICFBI., pp.140-143.

[9] Liang, Q. Wendelhag, I. Wikstrand, J. and Gustavsson, T. (2000) 'A multiscale dynamic programming procedure for boundary detection in ultrasonic artery images', IEEE Trans. Med. Imaging, vol. 19, no. 2,pp. 127–142.

[10] Loizou, C.P. Pattichis,C.S. Pantziaris,M. Tyllis, T. and Nicolaides, A. (2007), 'Snakes based segmentation of the common carotid artery intima media', Med. Biol. Eng. Comput., vol. 45, no. 1, pp. 35–49.

[11] Maulik, U. (2009) 'Medical Image Segmentation Using Genetic Algorithms', IEEE Transactions on information technology in biomedicine, Vol. 13, No. 2, pp.166-173.

[12] Molinari, F. Zeng, G. and Suri, J. S. (2010) 'Intima-media thickness: Setting a standard for a completely automated method of ultrasound measurement', IEEE Trans. Ultrason. Ferroelectr. Freq. Control, vol. 57, no. 5, pp.1112–1124.

[13] Ratnayake, K. and Aishy Amer, (2006), 'An FPGA-based implementation of Spatio-Temporal Object Segmentation', IEEE Trans. on ICIP, pp. 3265-3268.

[14] Santhiyakumari, N. Rajendran, P. Madheswaran, M. (2010) 'Medical Decision-Making System of Ultrasound Carotid Artery Intima–Media Thickness Using Neural Networks', J Digit Imaging, Society for Imaging Informatics in Medicine, pp.1112-1125.

[15] Santhiyakumari, N. Rajendran , P. Madheswaran, M. and Suresh, S. (2011) 'Detection of the intima and media layer thickness of ultrasound common carotid artery image using efficient active contour segmentation technique', International Federation for Medical and Biological Engineering, vol.49, no. 11, pp. 1299-1310.

[16] Santhiyakumari, N. Madheswaran, M. (2008) 'Non-invasive evaluation of carotid artery wall thicknessusing improved dynamic programming technique',Journal of Signal, Image and Video processing, pp. 183-193.

[17] Selzer, R. H. Mack, W. J. Lee, P. L. Kwong-Fu, H. and Hodis, H. N. (2001) 'Improved carotid elasticity and intima-media thickness measurements from computer analysis of sequential ultrasound frames', Atherosclerosis, vol.154, no.1, pp. 185–193.

[18] Silva, J. Rocha, R. Campilho, A. Azevedo, E. and Santos, R. (2010) 'Segmentation of the carotid intima-media region in B-mode ultrasound images', Image Vis.Comput., vol.28, no.4, pp.614–625.

[19] Stanley Osher, Tom Goldstein, Xavier Bresson,, (2010) 'Geometric Applications of the Split Bregman Method: Segmentation and Surface Reconstruction', J Sci Comput, pp. 272–293.

[20] C.T. Johnston, D.G. Bailey, K.T. Gribbon, (2005) 'Optimisation of a colour segmentation and trackingalgorithm for real-time FPGA implementation',Image and Vision Computing Newzealand, pp.422-427.

[21] Marie-Hélène Roy Cardinal, Jean Meunier, Gilles Soulez, Roch L. Maurice, Éric Therasse, and Guy Cloutier (2006), 'Intravascular Ultrasound Image Segmentation: A Three-Dimensional Fast-Marching Method Based on Gray Level Distributions',IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 25, NO. 5, pp.590-601.

[22] http:///www.who.int/mediacentre