Journal of Biology and Today's World
Journal home page: http://journals.lexispublisher.com/jbtw

Received: 21 March 2017 • Accepted: 30 May 2017

Research

doi:10.15412/J.JBTW.01060903

A Fast and Efficient Region based Aneurysm Segmentation Model for Medical Image Segmentation

Srinivas Thirumala[1*], Srinivasa Rao Chanamallu[2♠]

[1] Department of ECE, Aditya College of Engineering, Surampalem, A.P., India
[2] Department of ECE, University College of Engineering Vizianagram, JNTUK, Vizianagarm, A.P., India

*Correspondence should be addressed to Srinivas Thirumala, Department of ECE, Aditya College of Engineering, Surampalem, A.P., India; Postal code: 533437; Tel: +917729996255; Fax: +91; Email: tirumala.sri1@gmail.com.

♠Co-Correspondence should be addressed to Srinivasa Rao Chanamallu, Department of ECE, University College of Engineering Vizianagram, JNTUK, Vizianagarm, A.P., India; Postal code: 535003; Tel: +919441036921; Fax: +91; Email: ch_rao@rediffmail.com.

ABSTRACT

Aneurysm and blood vessel delineation from medical images facilitates efficient diagnosis of the Aneurysm and vessels (Stroke or Hemorrhage and Stenosis or malformations) and registration of patient images obtained at different times. Computer-aided diagnosis and detection of Aneurysms via Segmentation algorithms is a complex and multi-faceted issue in medical image processing, as adjoining vessels are the high-intensity structures whereas aneurysms are of low contrast and intensity. Obviously, segmentation is essential to identify the disease severity by change monitoring and also to know further Haemo-dynamic situation in critical cases. Change detection and further analysis gives the complete picture of the case of interest. For Brain tumor detection and analysis, there are several segmentation algorithms but only few are suitable for aneurysm detection and analysis. There is a necessity to provide an efficient segmentation model for aneurysm analysis, change detection and delineation which overcomes the limitations on speed and accuracy of other models. The objective of this paper is to first, apply local binary fitting (LBF), chan-vese (CV) models to aneurysm analysis. Then perform Region based Aneurysm Segmentation model frame work on data sheets of MR Angiography of brain. It is a perfect level set based Active contour model which converges in short span without requirement of any stability and termination criterions. The key feature of this model is that delineation is independent of choice of mask dimensions. Promising results are obtained with the proposed model.

Key words: Active Contours, Chan-Vese Model, LBF, Level set Method, Ruptured Aneurysm.

Journal of Biology and Today's World is published by *Lexis Publisher*; Journal p-ISSN 2476-5376; Journal e-ISSN 2322-3308.

1. INTRODUCTION

With the advances in segmentation methods computer aided diagnosis (CAD) and surgery become simple and invasive. Efficient medical image segmentation algorithms are developed to analyze cases of various modalities such as magnetic resonance (MR), computed tomography (CT), positron emission tomography (PET), Angiography etc. by researchers (1-3). Aneurysms are classified according to various criteria. However, shape cannot imply any risk factor. Saccular aneurysms are formed in vessel, filled by thrombus partially or fully and are of spherical shape. Their size may be up to 18cm. But, Fusi-form aneurysms may be identified in huge portions of ascending and transverse aortic arch, abdominal aorta with a size of 20cm. Identity of any aneurysm is based on diagnosis of MRA (Magnetic Resonance Angiography) or CTA (Computerized Tomography Angiography) data sheets (4). Generally, there are three treatment methods for aneurysm suffering people. First, one is simple non-surgical therapy. However, it's not the choice for risk cases. Then second or third method of treatment used is either surgical therapy (clipping) or endovascular therapy (coiling). Clipping method is used to prevent aneurysm from unnecessary bleeding. During this invasive surgery, a minute clip is placed across its dome. This surgical clip isolates aneurysm from its normal blood flow without blocking the minute neighborhood and associated artery. The clips are normally made up of titanium. The main limitation is clips are permanent. Coiling is the other surgical option for treatment of aneurysms. It is also called as endovascular embolization. Aneurysm is filled with coils of metal like platinum by using a micro catheter. It stops rupture. The main merit of it is that they are detachable with the help of fluoroscopic imaging guidance. Main target of this method is to cease rebleeding in ruptured aneurysm and also to stop rupture in unruptured aneurysms. It is applicable to small neck shaped aneurysm. Stent should be the best choice for wide neck shaped (Parental vessel) aneurysms. Hence, segmentation of aneurysm structures may be the repetitive task required for specialists to follow up further treatment. The advanced image processing algorithms are the best choice for analysis of various aneurysms. There are six kinds of most important cases of interest identified by us in our work. First, one is Case studies of neurology which discusses aneurysm at brain arteries and aqueductal hydrocephalus (huge water deposit due to blockage of some arteries) and diabetic neuropathy due to micro arteries of blood. The Second one is Case studies of cardiology (5). It includes mainly three types of abnormal widening. Those are heart, abdominal arteries and balloon angioplasty case studies (Therapeutic procedure to remove obstructions in arteries) related to macro arteries of blood. Third type of interest is in the Case studies of Rheumatology i.e. aneurysm at knee and leg arteries. Next type of case studies is ophthalmological case studies. The Micro aneurysms (MA) occur at eye are come under this type. These are the critical cases that are found in diabetic retinopathy in case of micro aneurysm problem prone arteries during last two decades. The fifth one is Case studies of Nephrology which include aneurysm near kidney (diabetic nephropathy) and the last case study is colonoscopic case studies (aneurysm at Intestine) etc. All these are abnormal findings at vessels and artery. Next woman case studies are also of special interest in critical cases i.e. Case studies of pregnant woman (formation and rupture of splenic artery aneurysms) and breast cancer woman's Case studies of Mammography (Aneurysm in heavy breast woman) etc. Segmentation is a task that is used to distinguish foreground from background (5). Angiography is the versatile visualization technique of aneurysm, associated arteries and parent blood vessels. Automatic segmentation of brain aneurysms via MRA or CTA data sheets is possible using various image-processing algorithms instead of manual segmentation by radiotherapist. Automatic segmentation is inaccurate and time consuming sometimes due to application of improper bias, noise and other artifacts available in the angiography datasheets (2, 4, 6). When there are some problems in flow of blood through arteries, blood vessels and if they are chronic (from many months) then they needs to be detected. Normally, f-MRI image modality gives a nice representation of blood flow through blood vessels, arteries. Hence, it is better to segment aneurysms along with malfunctioning arteries and blood vessels. In other aspect coils no longer allows blood flow into aneurysm. Delivery wire of coil allows physician to reposition the coil or to withdraw the coil if accurately placed i.e. once properly positioned, coil is removed using a charge by the process of electrolytic detachment from the delivery wire. If coils are not properly placed then repositioning has to be done. Some times after few months of endovascular embolization, Sometimes there may be change of position which further affects patient's health. In some other cases of aneurysm clot, there is an excess blood flow in blood vessels, arteries what actually they handle. Hence, Global intensity based Region segmentation from post treatment angiography (after coiling is made) data sheet will be the in dearth diagnosis tool for repositioning aneurysms and analysis of more blood prone arteries and parent blood vessels. This region based automatic segmentation results also help in prognosis task of treatment of ruptured aneurysm (after coiling) and unruptured aneurysms. Hence, region based segmentation i.e. segmentation of both aneurysms along with arteries is preferred over detecting & locating only the aneurysm. Snakes are the most widely used models for image segmentation. Many times synonymously, they are also referred as deformable models or Active contours (7, 8). Various types of snakes viz., GVF snakes, Water shed based snakes, Kalman snakes, Distance snakes, Stop & go snakes, Multidirectional snakes, Balloon snakes with nonlinear filtering, Selector snakes, Fourier type descriptors, Multiple seeds, Level sets, Geodesic deformable models, Quadratic snakes, GGVF, Topology adaptive snakes, Area and length snakes, Constrained snakes, Region competition snakes, 3D snakes and Sketch snakes etc. are suitable for medical image segmentation solutions. A typical snake is chosen for one application according to what type of ROI is to be detected and in which modality it is to be detected (9, 10). Snakes of different Shape and parameters are used in different case studies of different medical branches in a wide variety of applications. They are either parametric active contours or geometric active contours (11). Examples of Parametric contours are Snakes, GVF, Balloon forces whereas level sets are an illustration of Geometric active contours (12). Level sets given by Osher and Sethian are later used in medical image segmentation by Malladi *et al.* (13). There are edge based or region based level set based Active contour models (14). LBF, CV methods are the well-known Active contour models (ACM) to capture ROI (Region of interest) in any image. For medical image segmentation we use a region-based ACM known as LBF and it stands for Local Binary Fitting. The best inference of Piecewise constant models is LBF. Hence it may be used in those cases where local image information is required for segmentation of typical images which is full of intensity in homogeneities (15, 16). Kernel used in LBF is MS (Mumford-Shah) Model (16). MS energy functional is used for process of deformation of contour.

The Energy functional of LBF is:

$$\mathrm{E}\,(C, f_1, f_2) = \lambda\, E_x^{LBF}(C, f_1(x), f_2(x))\, dx \qquad (1)$$

Here C is segmenting curve and f_1 and f_2 imply the image intensities near each center point **x**. Its mathematical foundations are discussed clearly in (15-17). The important advantage of LBF based ACM is that there is no need of fitting functions regularization due to smoothing via the gaussian convolution (15). The presence of the distance regularizing term gives the second merit of no need of reinitialization (18). The main limitation of it is indentation (19). If complex and multiple intensity structures such as ruptured aneurysms are segmented using LBF based ACM then the contour cannot move properly to deep concavities i.e. indentation. Speed limitation is also more prominent in case of aneurysms of complex size and typical shape structures (from microscopic range to macroscopic range). CV Model stands for Chan-Vese method. It is a Piecewise Constant (PC) model. Energy functional Minimization by contours and a given number of constants is the solution for segmentation. Constants are average image intensity in each region of the image. Later of problems of PC CV Method are solved in piecewise smooth (PS) CV model. Several times these methods are computationally inefficient. The mathematical foundations are discussed in (10, 20). In Chan-Vese based active contour algorithm there is a flexibility to define contour without edges and initial contour can also possess the shape of rectangle. If image not consists of statistically homogenous regions then contour settles at false boundaries. The sources of non-statistical regions in MR images are due to RF coil's non-uniform field generation and object susceptibility. Overcoming this bottleneck of segmentation of these images is the utmost job for medical imaging research community. Chan-Vese ACM overcomes segmentation problem by minimization of MS Functional. CV based ACM advantage is a single parameter regularization coefficient is only employed to modify the energy (15). CV model is evolved from MS model. The energy functional is minimized by the method of steepest descent for capturing boundaries. It automatically terminates after capturing boundary. Its implementation steps are described in (20). In 2002 de Bruijne M et al. proposed Efficient Active Shape Model (ASM) based segmentation technique for Brain aneurysms (21). Intracranial aneurysm images diagnosed by CTA are segmented by a novel multi-level segmentation technique published by Y Wang et al. in 2016 (22). It is based on the Lattice Boltzman Method and level set with ellipse for segmentation. Another alternative is to use deep residual networks based segmentation methodology for detection of left atrial aneurysms in conventional CT images (23). Saccular aneurysms of brain identified in 2D Digital Subtraction Angiography (DSA) modality are segmented using a new semiautomatic method proposed in 2016 by Nisreen Sulayman, Moustafa Al-Mawaldi and Qosai Kanafani (24). A review paper provides detailed discussions on detection and segmentation of micro aneurysms in fundus images (25). These techniques can also be extendable to cerebral aneurysm segmentation. Another survey paper discusses applications of various available algorithms based Computer aided diagnosis (CAD) systems to segment aneurysm in ordinary CT, MR, PET image modalities, traditional angiography and special angiography MRA and CTA data sheets (26). Several authors are also trying to use the Computational fluid dynamics and equation modeling software's to analyze different types of brain aneurysm structures like Saccular, fusiform and also Abdominal Aortic Aneurysms (AAA). Related tools for this task are 3D Structural Modeling tools like Amira, Hyper Mesh etc. The usage of these tools provides an interactive platform to approximate and predict the status of aneurysm in live and future viz., in several cases of ruptured aneurysms by calculating wide variety parameters via considering a number of boundary conditions (27). It can check the aneurysm blood flow, systolic pressures, gradients in case of asymptomatic unruptured aneurysm and associated arteries and vessels (which are to be undergoing to the state of rupture in future). These various kinds of boundary conditions sets provide designers and physician team to a rough estimate of aneurysm behavior. i.e. how it handles blood flow, How it enlarges, its dome status, diameter, wall deformation details etc.

2. MATERIALS AND METHODS

Ruptured aneurysm is the cause of subarachnoid haemorrhages (SAH) in many critical brain aneurysm case studies (28, 29). Ideal placement of coil avoids aneurysm rupture in emergency cases (6). To clot and to fit coil perfectly according to aneurysm dimensions and shape needs the Remarkable segmentation report. Change of coil location due to unknown reasons is also a trivial problem. Existing algorithms such as LBF, CV Active contour models are failed sometimes to fit aneurysm boundaries, related arteries and blood vessel structures. Nowadays with the availability of a wide variety of kernel regression techniques, stability phenomena and termination criterions, we can improve above CV model performance in terms of accuracy but with increase in cost of computational time. RASM is the devised new segmentation model to detect and delineate aneurysm and associated blood vessel in various aneurysm data sheets. It stands for Region based Aneurysm Segmentation Model. Current section elaborates novel idea of our RAS Model and its implementation highlights. It relies primarily on the Fast Aneurysm and Blood Vessel Delineation Method (FABDM), Concepts of partial differential equation based level set evolution with adequate mask, energy functional minimization and stability criterion (17, 30). This is a compound model that utilizes both the global and local statistical information in such a way to get rid of problems with the distribution of inhomogeneous intensities in various aneurysm image data sheets (15). The main merit of this model is that choice of values for different parameters are independent of image intensity as well as texture variation. The kernel used is average kernel. The Frame work of this model consists of mainly four aspects. Initially run high speed active contour based FABDM on aneurysm data sheets. Second aspect is for Preprocessing of MRA DS (Data sheet). If high degree segmentation is not possible then preprocess aneurysm data sheets using MICO algorithm of chumming Li et al. which is an alternative to get optimized bias corrected images for better segmentation results (31). Hence, it is an optional aspect. Third aspect is regarding change detection of two successive (different) time angiography DS's of patient i.e. times before and after treatment or surgery. We need to go for change detection's identification via simple absolute difference method primarily then obtain the quantative analysis of those DS using Angio Quant package for minute changes identification. Hence, Third and Fourth aspects are meant for the purpose of change detection.

2.1. First aspect : Application of FABDM

The algorithm of Fast Aneurysm and Blood vessel Delineation Method (FABDM) may be formulated as seven steps in (17). Obviously it improves the performance than the conventional level set models in terms of computational speed and convergence.

2.2. Second aspect : Application of MICO algorithm on Data Sheets

It is an intermediate of step1 of FABDM (17). MICO stands for Multiplicative intrinsic component optimization. Actually it has been widely used in processing of Magnetic Resonance Images of brain (31). Hence, they are also tested on MRA DS of patients if segmentation fails due to any mismatch of mask defined over it. After obtaining bias field estimation of aneurysm DS, apply once again FABDM on preprocessed DS. They will give promising improvement in segmentation. Hence, it will be an optional step in RASM.

2.3. Third aspect : Change identification via Simple Absolute difference method

This is an optional step (step 7) of FABDM (17). It will be a guide to Endovascular, Neurosurgeons and other Neurointerventional community to suggest prognosis. If patient suffers with some problems of aneurysm even though after coiling procedure then Compare the segmentation results of before and after endovascular embolization by monitoring absolute difference between them. Even we can compare segmentation results during prognosis month by month after a predetermined dose rate. If the difference image is full black there is no need of repositioning the coil otherwise it is white then repositioning is needed or gives an observation of any new growth or rupture at aneurysm.

2.4. Fourth aspect : Change detection Quantitative analysis via Angio Quant Package

After identification of changes with our proposed simple absolute difference method we studied patient DS before and after treatment in dearth with a package called Angio Quant. Angio Quant is the tool to test Electronic micro scope (ESM) images of different Angio assays obtained after endothelialization process by original authors (32). We have tested it on aneurysm suffering patient DS. From this we can count no of junctions of aneurysm & blood vessels, no of complexes in aneurysms and length and size of them. This quantification analysis later tells whether ruptured or bleeding aneurysm is cured or not by comparing acquired parameters with parameters of aneurysm DS without treatment. This helps a lot for proper dose rate in case studies of different aneurysms and stroke (Hemorrhage) related problems.

3. RESULTS AND DISCUSSION

In current era of Medicine, Patient-specific cerebral-vascular hemo-dynamics plays a vital role in clinical methodology and related procedures. Segmentation model presents the fundamentals for developing aneurysm blood circulation dynamics and related computations, aneurysm shape models, haemo-dynamic situation, aneurysm growth, degree of rupture and severity for decision based treatment. During brain treatment normally abnormal brain impulses may be observed by EEG (Electro Encephalo Gram) segmentation. Alpha, Beta and Gamma etc. wave analysis via sophisticated filtering - tracking techniques indicate the normal, abnormal attitude, Fatigue conditions of the patient. If any severe abnormal condition or stress condition is observed, then we go for diagnosis using any modality scans. If MRI or CT diagnosis indicates any aneurysm and blood vessel related problems then in order analyze the aneurysm and blood flow in vessels we will consider Angiography data sheet. MRA and CTA are alternative for traditional angiography. Individual intermediate results for all methods are discussed. Tested Individual intermediate results of LBF, CV methods are shown in sub section 3.1 with sub sections 3.1.1, 3.1.2 respectively (for Figure 1 sub image (a) which is a T1-weighted MR Brain image Figure 2 (a)).

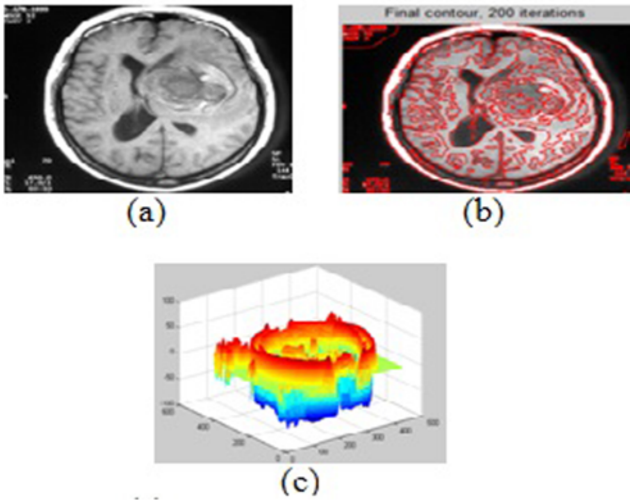


Figure 1. LBF Model Intermediate results

Later first aspect FABDM individual intermediate results are shown in sub sequent sub section 3.1.3. Next a relative result comparison of all case studies is shown in sub section 3.1.4 and with tabular column 1. Sub Section 3.2 shows MICO algorithm (Second Aspect) results. Sub section 3.3 clearly depicts the Change detection via absolute difference method (Third Aspect) results and finally Subsection 3.4 and tabular column 2 provides results of Change detection via Angio Quant tool.

3.1. FABDM Vs LBF & CV Method Results

3.1.1. LBF Method output with intermediate results

The LBF method segmentation intermediate results are shown in below Figure 1 by three windows (a), (b) and (c) [for Figure 2 (a)].

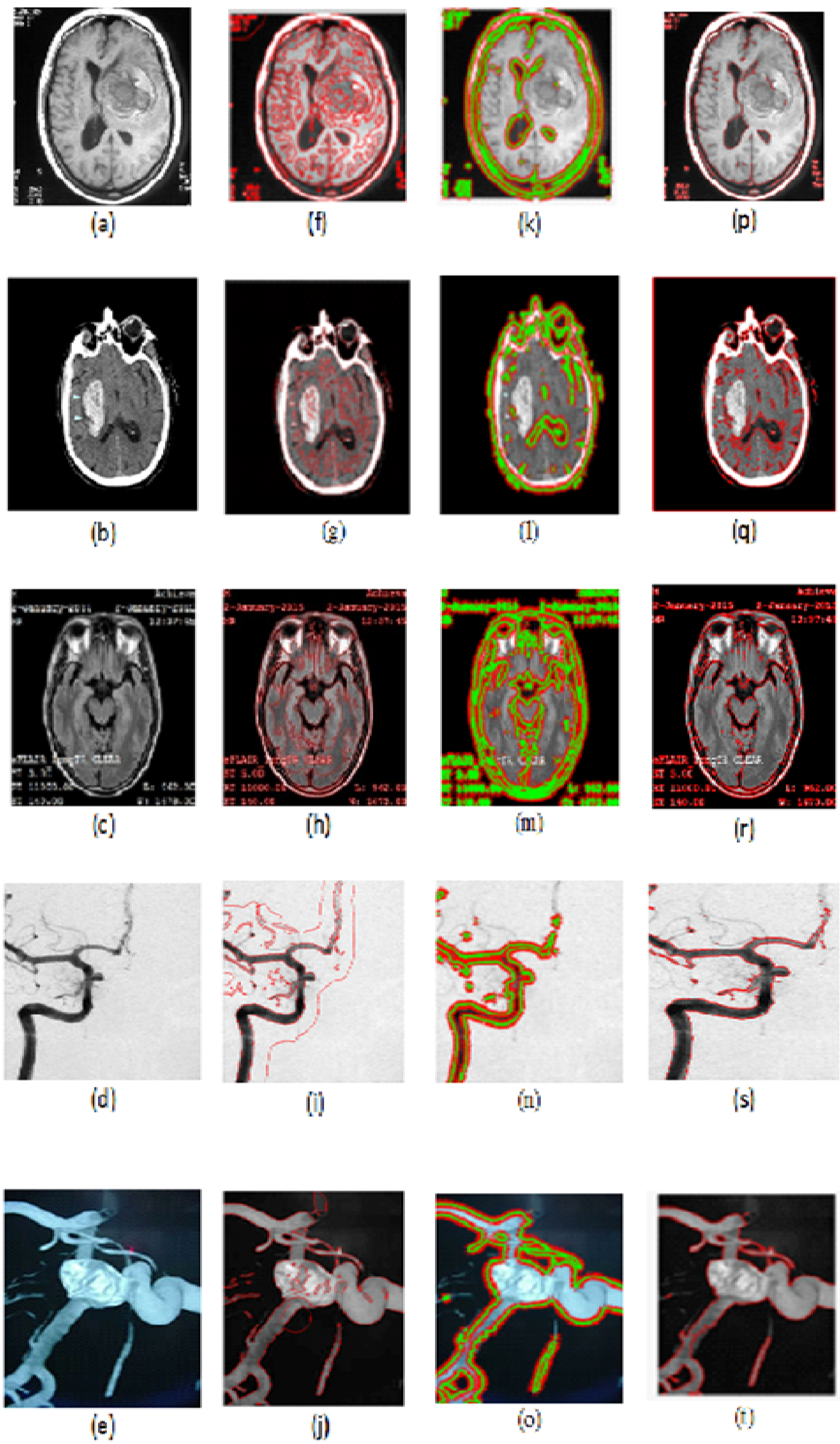


Figure 2. Relative results Comparison of three methods

They are test image, segmentation o/p and level set evolution respectively for further analysis. It is the implicit ACM among a wide variety of ACM'S. The choice of parameters is same for all images. Choice of parameters for all images analysis is:

$\lambda 1 = \lambda 2 = 1$ and nu=0.001*255*255 only.

3.1.2. CV Method ouput with intermediate results

Using below Figure 3 aneurysm segmentation intermediate results using CV method for Figure 2 sub image (a) are shown by four windows (a), (b), (c), (d) i.e. test image, and Initial contour, Segmentation output and Global segmentation o/p respectively.

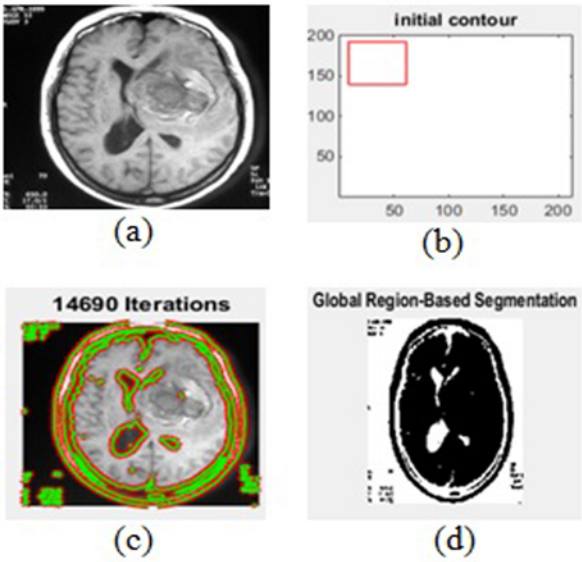


Figure 3. CV Model output with Intermediate results

3.1.3. FABDM output with results (Aspect I)

The FABDM segmentation results of aneurysm are shown in Figure 4 for Figure 2 (a) image. It is plotted as four windows. Top left window is test image, top right window is level set evolution, bottom left window is segmentation o/p and bottom right window is extracted o/p in white back ground for further analysis respectively.

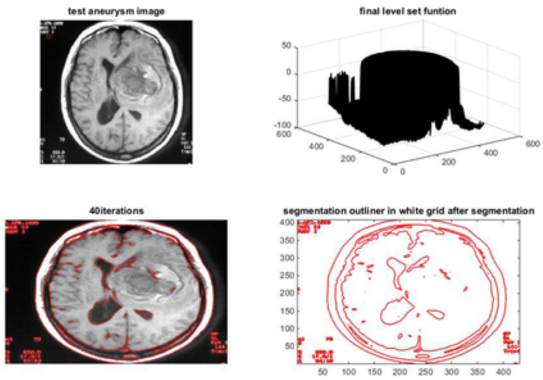


Figure 4. FABDM output with Intermediate results

3.1.4. Relative results of Tested three models

For aneurysms detection and location we have tested LBF, CV and FABDM active contour methods on available wide variety of MRA Data sheets. Actually LBF, CV models are used for tumor delineation in MR and CT scan images. However, we have tested them on Angiography data sheets. Even though we have tested on many images and data sheets due to length consumption of paper only few no of typical delineation results are posted using the Figure 2. Last portion of this section gives execution time of three models with tabular column1 i.e. 8 case studies in Table 1.

Table 1. Relative comparison of the three tested methods

Data sheet Type	Method	Convergence	Terminated Iteration No	Execution time in Sec.
Image 1 Data sheet Figure 2 (a) (Brain T1 weighted MRI)	LBF	Yes	200	78.17
	CV	Yes	14690	798.4
	FABDM	Yes	40	37.67
Image 2 Data sheet Figure 2 (b) (Brain T2 weighted MRI)	LBF	Yes	200	19.00
	CV	Yes	466	28.29
	FABDM	Yes	40	12.28
Image 3 Data sheet Figure 2 (c) (f-MRI FLAIR)	LBF	Yes	200	29.03
	CV	Yes	7024	30.04
	FABDM	Yes	40	15.78
Image 4 Data sheet Figure 2 (d) (Cerebral Angiography)	LBF	No	200	22.59
	CV	Yes	520	31.02
	FABDM	Yes	40	12.40
Image 5 Data sheet Figure 2 (e) (Post coiling Angiography Image)	LBF	Yes	200	15.40
	CV	Yes	1327	54.51
	FABDM	Yes	40	8.73
Image 6 Data sheet (PCMRA image)	LBF	No	200	23.57
	CV	Fails	1	-
	FABDM	Partial	40	14.14
Image 7 Data sheet (3D MRA Image)	LBF	Yes	200	32.96
	CV	Yes	2493	163.83
	FABDM	Yes	40	18.25
Image 8 Data sheet (May field Coiling)	LBF	Yes	200	29.73
	CV	Partial	715	43.08
	FABDM	Yes	40	13.98

However, image results are shown only for first 5 case studies among total 8 case studies. The images and results are shown in Figure 2 by column wise. Image (a) is a T1-weighted MR image that represents right-sided hemi paresis consists of large intra cerebral mass which causes an edema. The lesion found in this case is a giant internal carotid artery aneurysm of the brain. Image (b) is a T2-weighted MR image of a middle-aged woman with aneurysm indication from the left side to middle of the brain. Image (c) is a functional magnetic resonance image fluid attenuation inversion recovery (f-MRI FLAIR) long TR brain image with blood vessels obtained from Department of Radiology, GSL hospital, Rajahmundry. From these primarily we will identify the indication of aneurysm then further we go for angiography and fluoroscopy. All other 5 images discussed here are various angiography modalities. Image 4 is a data sheet of left oblique cerebral angiogram with multiple intracranial aneurysms viz., a middle cerebral artery and anterior communicating aneurysms. Image (d) is left oblique cerebral angiogram with a number of aneurysms such as a middle cerebral artery, anterior communicating aneurysms. Image (e) is a Cerebral Angiography of an aneurysm after endovascular embolization (post coiling image) to avoid the condition of clot. The silver colored portion of center region indicates coil placed at aneurysm dome in the image. Next 3 images are not shown but their results are only posted in Table 1 due to paper length consumption. Sixth case study image (whose image results are not posted) is PCMRA. This data sheet indicates aneurysm at basilar artery which is acquired by a MR Scanning system with 1.5T specification of GE Company of Kings College London's Neuroscience department. Subsequent two images whose image results are not posted are 3D MRA indicating the two infundibuli at the origins of the left AchoA and left PcomA and May field clinic aneurysm image after coiling treatment. The results are relatively compared in Figure 2. Figures (f), (g), (h), (i) and (j) are LBF model segmentation outputs. Similarly (k), (l), (m), (n) and (o) are CV model segmentation outputs and (p), (q), (r), (s) and (t) are our recently developed outputs of FABDM segmentation for same (a), (b), (c), (d) and (e) sub images respectively. The relative comparison of the three models is given by the Table 1, the type of angiography data sheet i.e. type of scan image or type of angiogram is given in the first column, Tested model for aneurysm study viz., LBF or CV or FABDM is second column. The accuracy of aneurysm boundary detection via above models indicated as yes or no or partial by third column (as it always implies the severity of indentation). Iteration number (where respective active contour model is terminated) is given by forth column. The last column of table indicates the time elapsed (taken) by main loops for their execution in seconds. But FABDM parameters selection may be unique for all case studies (with very limited user interaction). Hence, it reflects automation for the complete extraction of the aneurysm and vessels. From the Table 1 and Figure 2, we can conclude that LBF method fails to converge to boundaries in case of (b), (c), May field coil aneurysm image where as all other images are taking more time to converge to precise boundaries. All these results of images are carried out with 64 bit windows OS based Intel i5 processor @ 1.7GHz- 2.4GHz system (with 4GB RAM) using MATLAB. LBF requires more time than FABDM but less time than CV method due to mask match problem. All results are considered at 200 iterations then also many times they are not converging to precise boundaries.

3.2. MICO output with Intermediate Results (Aspect II)

The MICO method aneurysm segmentation intermediate results are shown in below Figure 5 by four windows (a), (b), (c) and (d) for Figure 2 sub image (e) as Test aneurysm image, Bias field, Bias corrected image and segmentation o/p respectively for further analysis.

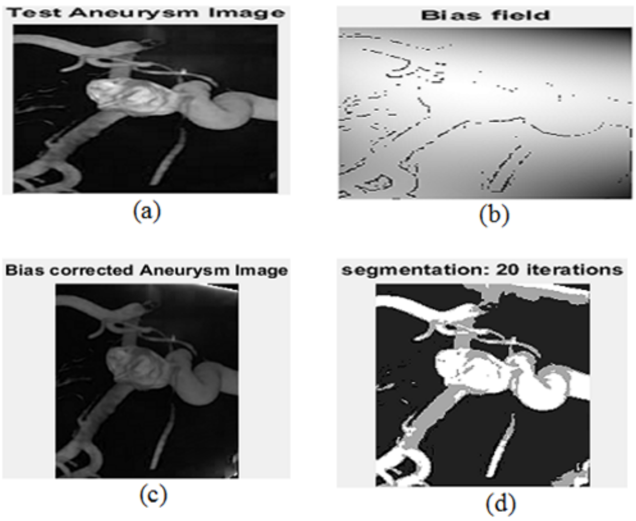


Figure 5. MICO Algorithm Intermediate results

3.3. Change detection Preliminary Identification (Aspect III)

The FABDM is applied for two images of pre coiling and post coiling images with initial mask as shown below in Figure 6 with sub images (a) and (b) (as it is the fast method for obtaining the segmentation results among three models). The change detection image generated via absolute difference method is shown in Figure 6 sub image (c). If the change detection image is full black then there is no need of repositioning of coil.

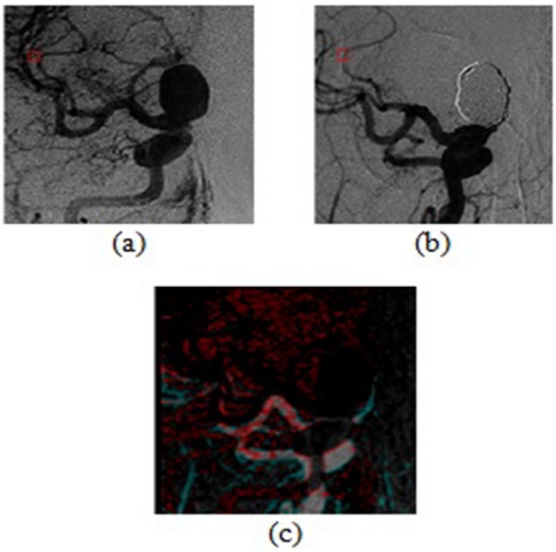


Figure 6. Change detection Identification of aneurysm images

Otherwise it appears as white in obtained difference image then repositioning is needed or it is an indication of any new growth or rupture at aneurysm or blockage of any artery or parent vessel inflation.

3.4. Change detection Analyis by Angio Quant (Aspect IV)

The Angio Quant is applied for two images of pre coiling and post coiling images. The change detection of images is carried out via Angio Quant. The analysis can be indicated by a tabular column 2. First column tells about type of patient aneurysm data sheet, Second tells how many aneurysm complexes are identified. Next sub sequent third, fourth, fifth indicates length, size, no of junctions respectively. With this quantification out puts we know about ruptured aneurysm coils placement and healing status.

Table 2. Change detection analysis by Angio Quant

Data sheet Type	No of aneurysm complexes	Length	Size	No of junction
Pre Coiling angiography image	5	1979.38	12872	65
Post Coiling angiography image	8	930.23	5871	15

First column tells about type of patient aneurysm data sheet, Second tells how many aneurysm complexes are identified. Next sub sequent third, fourth, fifth indicates length, size, no of junctions respectively. With this quantification out puts we know about ruptured aneurysm coils placement and healing status.

4. CONCLUSION

RASM provides the optimum results for aneurysm analysis with the help of high-speed active contour model FABDM. So far, image examples discussed in the paper also provides accurate segmentation with LBF, CV models but with the change of the mask and parameter selection. Hence, increase in computational cost and makes the models much semi-automatic and provides only limited analysis. Proposed segmentation model framework is efficient and more analytic and will be helping aid for Neuro specialists and surgeons during different aspects of treatment of aneurysms as it is automatic. During the invasive treatment of an aneurysm the above modifications makes Pre and Post-operative diagnosis, endovascular coiling and clipping treatments very simple. In future, it may also be tested and validated on intestine, bone and a wide variety of brain aneurysms case studies of different aneurysm modalities such as CTA, BSCTA, PCMRA, 3DRA etc. For automatic detection of aneurysms with good degree of segmentation accuracy and also to maintain substantially wanted hemodynamic analysis, we can combine the current three methods along with available structure modeling software. Change detection between aneurysm data sheets during prescribed time slots as predicted by physician via absolute difference image can be improved by adopting the concept of dissimilarity map (DM) followed by a steering kernel. The best dissimilarity for analysis is cosine dissimilarity. Threshold based DM'S can reduce the difficulties in change detection of typical aneurysm structures.

ACKNOWLEDGMENT

The authors thank to the GSL Medical Hospitals and Trust, Rajahmundry, A.P., India, Med pix, Medline central Inc, May field clinic, DICOM Inc. and Brain aneurysm foundation for online databases and information of data sheets. Authors also express overwhelming gratitude to the famous MICO tool authors Chumming Li et al. and Angio Quant tool authors Antti Niemistö et al. (as we used them as important processing steps)

FUNDING/SUPPORT

Authors did not inform any Funding report/ Support details.

AUTHORS CONTRIBUTION

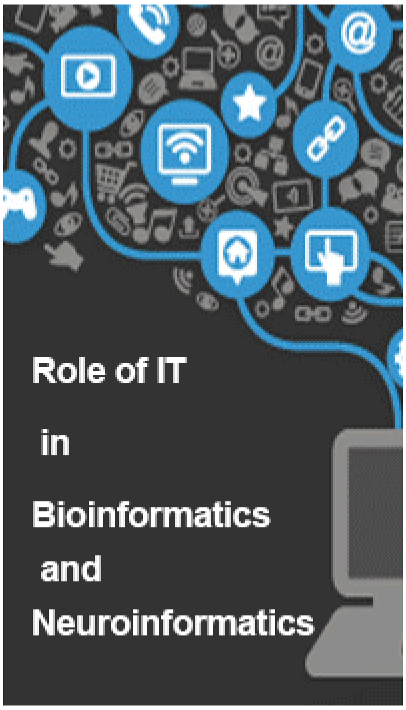
Authors informed that the work submitted is a not an individual author work, it's a collective work by two authors.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

REFERENCES

1. Angenent S, Pichon E, Tannenbaum A. Mathematical methods in medical image processing. Bulletin of the American Mathematical Society. 2006;43(3):365-96.
2. Choi W-P, Lam K-M, Siu W-C. An adaptive active contour model for highly irregular boundaries. Pattern Recognition. 2001;34(2):323-31.
3. Zhu W, Chan T. A variational model for capturing illusory contours using curvature. Journal of Mathematical Imaging and Vision. 2007;27(1):29-40.
4. Law MW, Chung AC. Segmentation of intracranial vessels and aneurysms in phase contrast magnetic resonance angiography using multirange filters and local variances. IEEE Transactions on image processing. 2013;22(3):845-59.
5. Dougherty G. Digital image processing for medical applications: Cambridge University Press; 2009.
6. Hernandez M, Frangi AF. Non-parametric geodesic active regions: Method and evaluation for cerebral aneurysms segmentation in 3DRA and CTA. Medical image analysis. 2007;11(3):224-41.
7. Withey DJ, Koles ZJ. A review of medical image segmentation: methods and available software. International Journal of Bioelectromagnetism. 2008;10(3):125-48.
8. Pham DL, Xu C, Prince JL. Current methods in medical image segmentation Annual review of biomedical engineering. 2000;2(1):315-37.
9. Makhanov SS, Active contours in medical image processing. Theory and applications. 5th International Conference on Knowledge and Smart Technology (KST); 2013.
10. Bojsen-Hansen M. Active contours without edges on the GPU. Project Paper For The Course In Parallel Computing For Medical Imaging And Simulation. 2010:1-8.
11. Subasic M, Loncaric S, Sorantin E,. Shape-specific adaptations for level-set deformable model-based segmentation. Proceedings of Computer Vision Winter Workshop; 2001;104-13.
12. Paragios N, Deriche R. Geodesic active contours and level sets for the detection and tracking of moving objects. IEEE Transactions on pattern analysis and machine intelligence. 2000;22(3):266-80.
13. Sethian JA. Level set methods and fast marching methods: evolving interfaces in computational geometry, fluid mechanics, computer vision, and materials science: Cambridge university press; 1999.
14. Terzopoulos D. Deformable and functional models. Computational Vision and Medical Image Processing: Springer; 2011. p. 125-43.
15. Wang L, Li C, Sun Q, Xia D, Kao C-Y. Active contours driven by local and global intensity fitting energy with application to brain MR image segmentation. Computerized Medical Imaging and Graphics. 2009;33(7):520-31.
16. Nakhjavanlo BB, Ellis T, Raoofi P, Dehmeshki J. Medical Image Segmentation Using Deformable Models and Local Fitting Binary. World Academy of Science, Engineering and Technology, International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering. 2011;5(4):168-71.
17. Srinivas T, Rao CS. Fast Aneurysm and Blood vessel Delineation Method. International Conference on Soft Computing Techniques in Engineering and Technology (ASCTET), 2016:115-120.
18. Li C, Xu C, Gui C, Fox MD,. Level set evolution without re-initialization: a new variational formulation. Computer Vision and Pattern Recognition, 2005 CVPR 2005 IEEE Computer Society Conference on; 2005: IEEE.
19. Xu C, Prince JL. Snakes, shapes, and gradient vector flow. IEEE Transactions on image processing. 1998;7(3):359-69.
20. Chan TF, Vese LA. Active contours without edges. IEEE Transactions on image processing. 2001;10(2):266-77.
21. de Bruijne M, van Ginneken B, Viergever MA, Niessen WJ. Interactive segmentation of abdominal aortic aneurysms in CTA images. Medical Image Analysis. 2004;8(2):127-38.
22. Wang Y, Zhang Y, Navarro L, Eker OF, Corredor Jerez RA, Chen Y, et al. Multilevel segmentation of intracranial aneurysms in CT angiography images. Medical physics. 2016;43(4):1777-86.
23. Wang L, Li S, Chen Y, Lin J, Liu C,. Structure Fusion for Automatic Segmentation of Left Atrial Aneurysm Based on Deep Residual Networks. International Workshop on Machine Learning in Medical Imaging NLMI; 2016: Springer, 10019:262-70.
24. Sulayman N, Al-Mawaldi M, Kanafani Q. Semi-automatic detection and segmentation algorithm of saccular aneurysms in 2D cerebral DSA images. The Egyptian Journal of Radiology and Nuclear Medicine. 2016;47(3):859-65.
25. Powar P, Jadhav C. A Survey of Microaneurysms Detection using Segmentation Techniques in Fundus Images. transformation. 2016; 135(1):32-34.
26. Arimura H, Magome T, Yamashita Y, Yamamoto D. Computer-aided diagnosis systems for brain diseases in magnetic resonance images. Algorithms. 2009;2(3):925-52.
27. Voß S, Glaßer S, Hoffmann T, Beuing O, Weigand S, Jachau K, et al. Fluid-Structure Simulations of a Ruptured Intracranial Aneurysm: Constant versus Patient-Specific Wall Thickness. Computational and Mathematical Methods in Medicine. 2016; Article ID 9854539:1-8. http://dx.doi.org/10.1155/2016/9854539.
28. Kirkpatrick P. Subarachnoid haemorrhage and intracranial aneurysms: what neurologists need to know. Journal of Neurology, Neurosurgery & Psychiatry. 2002;73(suppl 1):i28-i33.
29. King Jr JT. Epidemiology of aneurysmal subarachnoid hemorrhage. Neuroimaging Clinics of North America. 1997;7(4):659.
30. Chaudhury KN, Ramakrishnan K. Stability and convergence of the level set method in computer vision. Pattern Recognition Letters. 2007;28(7):884-93.
31. Li C, Gore JC, Davatzikos C. Multiplicative intrinsic component optimization (MICO) for MRI bias field estimation and tissue segmentation. Magnetic resonance imaging. 2014;32(7):913-23.
32. Niemisto A, Dunmire V, Yli-Harja O, Zhang W, Shmulevich I. Robust quantification of in vitro angiogenesis through image analysis. IEEE transactions on medical imaging. 2005;24(4):549-53.



Guest Editors:

Prof. Deepshikha Bhargava
Amity University Rajasthan – India
dbhargava1@jpr.amity.edu

Dr. Ramesh C. Poonia
Amity University Rajasthan – India
rameshcpoonia@gmail.com

Dr. Swapnesh Taterh
Amity University Rajasthan – India
staterh@jpr.amity.edu

This paper is published as one of the selected papers that were presented at:
International Conference on Smart Computing and Communication (SmartTech-2017).

Special Issue on: