EXTRACTION OF VESSELS FROM MRA IMAGES: CONCISE COMPARISON, REVIEW, CHALLENGES, AND PROPOSE

KALIM QURESHI

Department of Information Science, Kuwait University
E-mail: kalimuddinqureshi@gmail.com

Abstract- The automatic extraction of brain vessels from Magnetic Resonance Angiography (MRA) has found its application in vascular disease diagnosis, endovascular operation and neurosurgical planning. In this paper we first present a concise methodology, pros & cons of well-known vessel extraction techniques. The short survey of latest development in the area of vessel extraction by using region growing algorithms is present. Then we detail the main challenges of vessel extraction and segmentation area. Based on review and our experience in the area, we finally present enhancement in region growing algorithm. Our proposed algorithm shows performance improvement as compare to traditional region growing algorithm.

Key words- Image processing, segmentation, region growing, medical imaging, vessels, MRA

I. INTRODUCTION

Segmentation is a process of partitioning an image into regions on the basis of homogeneity of desired features [1]. Segmentation plays key role in the field of medical imaging and is applied in numerous applications i.e. extraction of blood vessels, detection of tumors, image registration, atlas matching, surgical planning etc. [2]. Images obtained from segmentation are further used in medical applications like diagnosis of different diseases, treatment planning, study of anatomical structure and computer-integrated surgery [3]. Segmentation techniques are depended on the following factors:

- Imaging modality
- Application domain
- Manual, semiautomatic or automatic method
- Specific features

II. COMPARISON OF VESSELS EXTRACTION TECHNIQUES

Segmentation plays a vital role in the diagnosis of vascular diseases. Segmentation techniques are categorized for both general applications and specifically for blood vessels extraction. According to [4] blood vessels segmentation algorithms are categorized as follows:

- Edge oriented techniques
- Region based techniques
- Active contour techniques
- Hybrid techniques

2.1 Segmentation using edge-oriented techniques

Intensity values at edges of an image are very high as compared to other regions [5-7]. An abrupt change in intensities is noted at each edge point, which implies rate of change for which derivative is calculated and is called gradient of an image. For a given image I(x, y) the gradient of an image can be presented as:

$$d_x = \partial I/\partial x \quad (1)$$

$$d_y = \partial I/\partial y \quad (2)$$

As continuous differentiation of digital image is not possible due to its discrete nature, so gradient of an image is calculated by differencing, as given below:

$$d_x = I(x+1, y) - I(x, y) \quad (3)$$

$$d_y = I(x, y+1) - I(x, y) \quad (4)$$

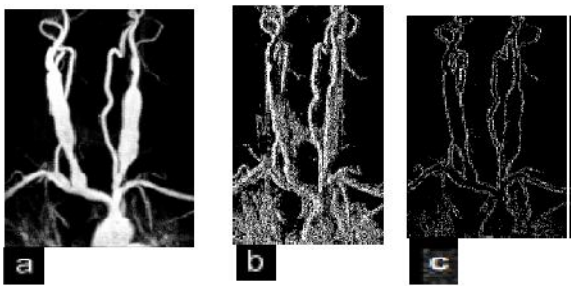

Figure 1. Example of an edge detection (a) Original image of neck MRA, (b) gradient of an image, (c) edge of an image after applying sobel filter.

An edge detection of neck MRA is illustrated in figure 1. The gradient of an image contains noise and does not result desired edges, shown in figure 1(b). Reason is that all the intensity values with abrupt change are included in the region. In order to get edges only, any filter operator like sobel, canny, laplacian (in case of second order derivative) etc. is apply to the gradient of an image, which removes unwanted region. For example in case of a 3x3 sobel edge operator, there are two 3x3 masks which are given in table 1.

Table 1. Filtering results of two kernals

Kernal 1 = G_x			Kernal 2 = G_y		
-1	0	1	-1	-2	-1
-2	0	2	0	0	0
-1	0	1	1	2	1

2.1.1 Pros

- Provides ease for segmentation by defining boundaries of required regions.
- No previous knowledge is required.
- No user interaction is needed.
- It is a time consuming technique.

2.1.2 Cons

- Detection of edges is dependent on the quality of input images. Edge detection methods do not always provide complete edges as shown in figure 2(b). Original image of brain in figure 2(a) is not clear therefore algorithm was not able to detect edges properly.
- It can define just boundary of required regions but can't extract whole object like blood vessels.
- As noises have high intensity values so they also become part of edges.
- Results are depended on gradient masks.

2.2 Active contour techniques

Active contours that are also known as snakes or deformable models are model-based techniques finding object contours using parametric curves that deform under influence of internal and external forces [8-11]. After initialization of any curve close to the boundary of an object by the user a snake that is set of connected points starts deforming and moving towards the desired object boundary. Each snake is basically assigned with energy that either rises or falls depending upon the forces that act on it. Internal forces serve to impose smoothness constraints on the contour while external forces pull the snake towards the desired image features like lines and edges. Figure 3 depicts the resultant image of active contour highlighting the region of tumor in brain.

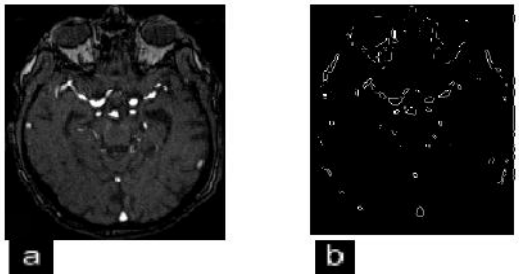

Figure 2. (a) Original image of brain, (b) incomplete detected edges of an image.

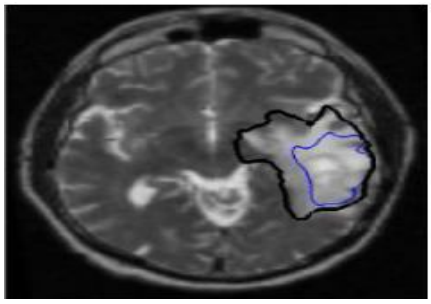

Figure 3. Detection of brain tumor using active contour

2.2.1 Pros

- This technique is suitable for detection of large size objects (vessels) like segmentation of coronary arteries or detection of brain tumors.
- It also works well for occluded, convoluted and twisted blood vessels as described in figure 4.

2.2.2 Cons

- Manual selection of scale factor is required.
- It does not work for noisy images.
- In case of thin and complex vessels this technique is unable toextract whole tree of vessels.
- It is computationally slow because of its complex nature

2.3 Region growing technique

Region growing technique is based upon following two factors:

- Selection of seed points.
- Selection of homogeneity criteria.

Both seed points and homogeneity criteria can be selected manually by the user or automatically by the program. Region growing starts from seed points where the neighbors of every seed point are examined to check whether they are sufficient similar to the seed according to a homogeneity criterion [12-14]. All those neighbor pixels of a seed that satisfy the homogeneity criteria condition are added to the region and the process is continue until the neighbors of all the seeds are visited. At the end only required region of interest (vessels) are obtained.

2.3.1 Pros

- It is capable of correctly segmenting regions that have the same properties and are spatially separated.
- As it suppresses the noise so vessels can be detected in noisy images too.
- The whole tree of vessels can be extracted.
- In case of automatic region growing technique no user interaction is required.
- It generates connected regions.

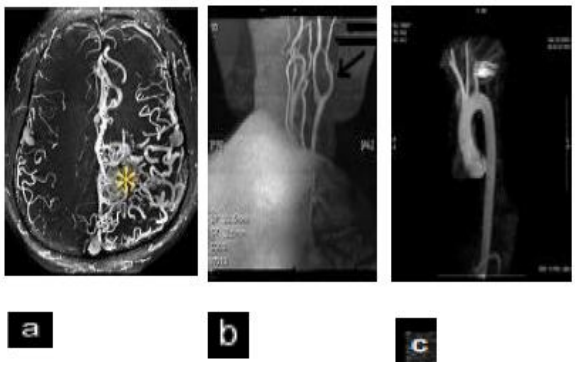

Figure 4. (a) Image of occluded blood vessels, (b) image of convoluted blood vessels, (c) image of twisted blood vessels.

2.3.2 Cons

- Automatically region growing based techniques are usually computationally slow because of selection of seed points and homogeneity criteria.

All the results are dependent on the selection of initial seeds point and homogeneity criteria.

2.4 Hybrid approaches

Hybrid approaches are the combination of strengths of all the above three discussed categories [16]. The main drawback of hybrid technique is that they are computationally slow due to integration of multiple techniques. Some of the important features of edge oriented, active contour and region growing techniques are described in table 2.

From above discussion it is concluded that region-growing technique is insensitive to noise and also has the ability to detect whole tree of vessels. Both of these parameters are considered important for segmentation of vessels. Here our focus will be on region growing technique for extraction of vessels using MRA images whose literature review is given below.

Table 2. An overview of comparison of discussed techniques

Techniques	*Prior knowledge*	*Not Sensitive to noise*	*Simplicity*	*Whole tree detection-*
Edge oriented	*No*	*No*	*Yes*	*No*
Active contour	*Yes*	*No*	*No*	*No*
Region growing	*Yes*	*yes*	*Yes*	*Yes*

III. CHALLENGING ISSUES OF VESSEL SEGMENTATION ALGORITHMS

In order to solve the intensity range problem for the segmentation of blood vessels, a range of strategies based upon region growing have been proposed by various authors:

- In order to validate the accuracy of vessel segmentation, methodologies must be introduced.
- Automatic selection of threshold must be developed for all approaches, as currently most of the techniques are dependent on the manual selection of threshold.
- Need of methods that automatically derive parameters locally as well as globally.
- For improvements in the results of segmentation efficient pre-processing and filtering techniques must be promoted.
- Introducing methods for connection of broken parts of vessel with the help of partial voluming or filtering during segmentation.

IV. PROPOSED REGION GROWING ALGORITHM (PRGA)

PRGA is divided into following phases:

- Selection of proper threshold value on the basis of maximum intensity values of all slices.
- Selection of starting slice for appropriate seed point on the basis of threshold.
- Segmentation of vessels using region growing algorithm.

In the traditional region growing algorithm, results of segmentation are totally dependent on the selection of seed point [32, 34]. An appropriate seed point results in quality segmentation. However, in the majority of MRA datasets, the start of the slices does not contain any required information. As a result of this, we have not applied region growing algorithm directly on the first slice. In order to begin from the required region, we have developed an automatic threshold value. To calculate the threshold, the maximum intensity value of each slice is obtained and stored in an array denoted as max_list. From this max_list, we then find the maximum and minimum intensity values i.e. m_1 and m_2 respectively. The flow chart of proposed PRGA is shown in figure 5.

V. EXPERIMENT SETUP AND MEASURED RESULTS

Details of datasets used in the experiment are given in Table 3. The vessels segmentation of head MRA for dataset 1, using a region growing algorithm without any enhancement, is shownin Figure 6. Datasets used for enhancements are given in Table 4.

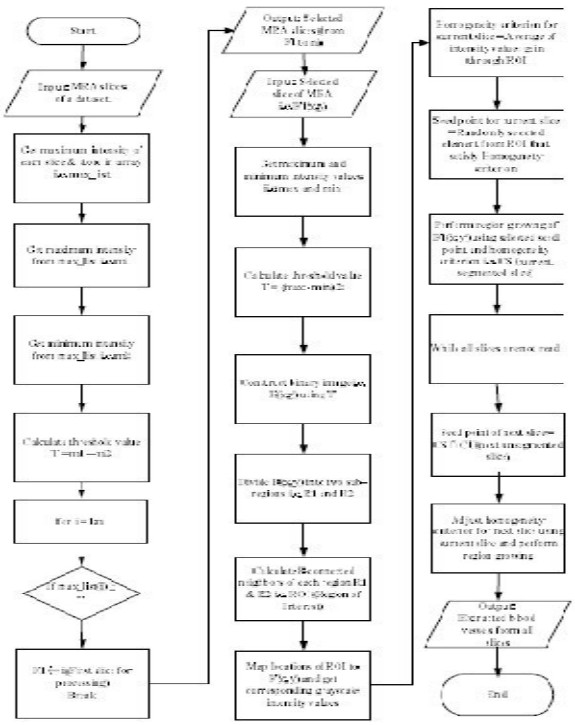

Figure 5 Flow Diagram for PRGA

CONCLUSION

The segmentation of blood vessels is an active research area which plays a significant role in many medical applications including diagnosis, surgery planning and radiation treatment. In this paper we presented various the pros and cons of several of vessels extraction techniques, short survey of MRA region growing algorithms, challenges of vessel segmentations algorithms and a PRGA has been proposed in this paper. PRGA has been tried on two patients of MRA datasets (1 head, 1 renal arteries) of different resolutions and has provided pleasing results.

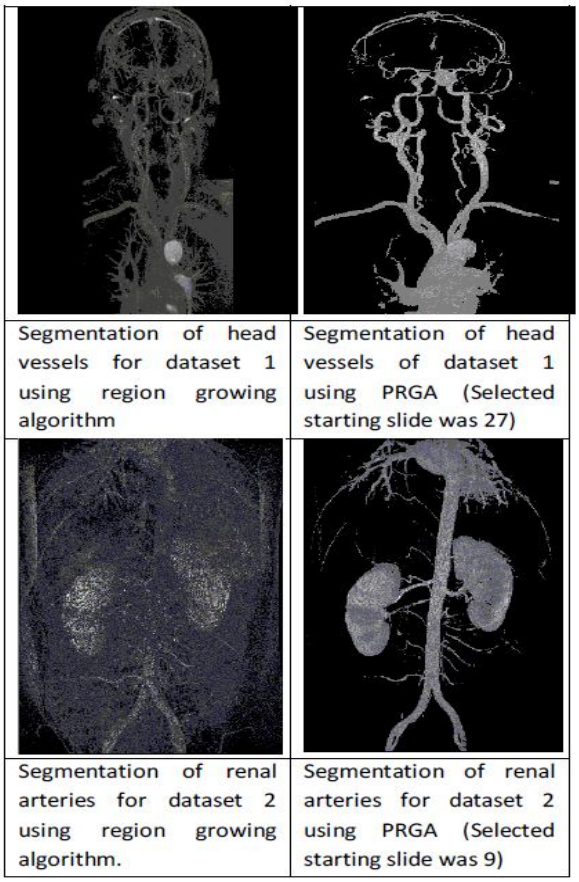

Figure 6. Comparison of PRGA with usual RGA

REFERENCES

[1] Bezdek, J.C., Hall, L.O., Clarke, L.P. (1993), Review of MR image segmentation techniques using pattern recognition. Med. Phys. 20, 1033-1048.

[2] Babin, D., Bock, J.D., D.B., Pizurica, A., Philips, W. (2007). The shortest path calculation between points of interest in 3D MRI images of blood vessels.295-298.

[3] Kass, M., Witkin, A., Teropoulos, D. (1988). Snakes:active contour models. Int J Comput Vis. 1, 321-331.

[4] Luo, S. &Zhong, Y. (2005). Extraction of brain vessels from magnetic resonance angiographic images: concise literature review, challenges and proposals. Engineering in Medicine and Biology 27th Annual IEEE Conference.1422-1425.

[5] Vincent, O.R. &Folorunso, O. (2009). A descriptive algorithm for sobel image edge detection.Proceedings of Informing Science & IT Education Conference.

[6] Torre, V. &Poggio, T. A. (1986). On edge detection. IEEE Trans PAMI. 8, 147-163.

[7] Davies, L.S. (1975). A survey of edge detection techniques.Computer Graph. And Image Proc. 4,248-270.

[8] Marr, D. &Hildreth, E. (1980). Theory of edge detection. Proc. Roy. Soc. London. 27, 187-217.

[9] Cohen, L. (1991). Note on active contour models and balloons. Comput Vis Graphics Image Process. 53, 211-218.

[10] Xu, C & Prince, J.L. (1998). Snakes, shape and gradient vector flow. IEEE Trans Image Process. 7, 359-369.

[11] Chang, Y.L., Li, X. (1994). Adaptive image region growing.IEEE Trans Image Process. 3, 868-873.

[12] Kirbas, C. &Quek, F.K. (2003). A review of vessel extraction techniques and algorithms.Third IEEE Symposium on BioInformatics and BioEngineering.238-245.

[13] Adams, R. &Bischof, L. (1994). Seeded region growing.IEEE Trans. Pattern Recogn.Mach Intell. 16, 641-647.

[14] Pratt, W.K. (1991). In: Digital Image Processing. New York: John Wiley & Sons.

[15] Mubbashar Saddique. Jawad Haider Kazmi, and Kalim Qureshi, “A Hybrid Approach of Using Symmetry Technique for Brain Tumor Segmentation”, Journl of Computational Mathematical Methods in Medicine, Volume 2014, Article ID 712783, http://dx.doi.org/10.1155/2014/712783

[16] J. H. Kazmi, K. Qureshi, H. Rasheed, "An implementation of SAN filter and edge sharpening method for MRA images", Malaysian journal of computer science, Vol. 20, pp. 99-114, 2007.

★★★