A Survey of Vessel Segmentation in Coronary Angiogram Image

Harsha P. Jawale
Department of Electronics and Telecommunication Engineering
J.T.Mahajan college of engineering, Faizpur.
Maharashtra,India

K.S.Bhagat
Assistant professor, Department of Electronics and Telecommunication Engineering
J.T.Mahajan college of engineering, Faizpur.
Maharashtra,India

Abstract-Coronary heart disease has been one of the main threats to human health. Coronary angiography is taken as the gold standard for the assessment of coronary artery disease. However, sometimes the images are difficult to visually interpret because of the crossing and overlapping of vessels in the angiogram. The main trouble in automatic extraction of coronary artery tree in angiographic images includes: little signal-to-noise proportion because of deprived X-ray diffusion, vessel overlays and superimposition of the other tissues. Accurate extraction of coronary artery tree from coronary angiograms is important for the diagnoses, treatment and clinical study of various coronary artery diseases. For this it is necessary to perform blood vessel segmentation of coronary X-Ray angiograms for exact analysis. There are various different methods invented for this purpose having some advantages and disadvantages as well.

Keywords – Coronary angiography, X-Ray angiogram, vessel segmentation.

I.INTRODUCTION

According to the World Health Organization, cardiovascular diseases such as coronary heart disease are the first worldwide cause of death [1]. Cardiovascular disease takes away more than 12 million lives each year[1]. It is often caused by coronary artery stenosis and blockage. Coronary artery play an extremely important role in the supply of blood to the heart and coronary atherosclerosis is the main reason of heart damage and myocardial infarction. A coronary angiogram is a special X-ray test done to find out if your coronary arteries are blocked or narrowed, where and by how much. Vessel extraction from X-ray angiograms has been a challenging problem for several years. There are several problems in the extraction of vessels including: weak contrast between the coronary arteries and the background, unknown and easily deformable shape of the vessel tree and strong overlapping shadows of the bones.

X-ray Coronary angiography is taken as the best for visualizing the morphology and the assessment of coronary artery disease. In order to improve the level of clinical diagnosis, the extraction and segmentation of coronary artery from X-ray angiographic images is very necessary. At the same time extracting distinct vascular patterns is a crucial premise to vascular quantitative analysis.

II.SURVEY OF SEGMENTATION

Many segmentation methods have been used to visualize blood vessel structures in the angiograms. These blood vessel segmentation methods may be classified as follows: Pattern recognition technique, model based approaches, tracking based approaches ,neural network based methods, fuzzy and artificial intelligence-based methods. Although segmentation methods are divided in different categories, sometimes multiple techniques are used together to solve different segmentation problems.

Poli and Valli[2] proposed a computationally efficient algorithm based on a set of linear filters, obtained as linear combinations of properly shifted Gaussian kernels, sensitive to vessels of different orientation and radius. Another type of linear filter, the morphologically connected set filter was utilized by Wilkinson and Westenberg to capture filamentous structures[3]. Togather with a shape criterion that could distinguish filamentous structures from others connected set filters could help to extract filamentous details without distortion. Similarly Eiho, Qian and Zana, Klein presents an algorithm based on mathematical morphology and curvature evaluation for the detection of vessel-like patterns in a noisy environment[4,5]. Morphological operators such as erosion, dilation and top-hat to enhance the shape of the artery and remove other points.

These methods were unable to suppress sudden noise and edge noise and were less efficient in capillaries. These methods searched for the local orientation of a vessel to perform anisotropic smoothing without blurring its edge. While Krissian et al. performed a particular version of anisotropic diffusion[6].They presented a new approach to anisotropic diffusion based on a multidirectional diffusion flux. The diffusion flux is decomposed in an orthogonal basis, effectively enabling enhancement of contours as well as diffusion along the contours. Orkisz et al.used a kind of filter bank called 'sticks' which could be seen as a set of directional structuring elements[7].

The main disadvantage of the methods in this category is that they can hardly detect vessels in a wide range due to the fixed scale analysis. Although these algorithms can be extended to multiple scales by using sticks of variable length, the computation time would increase greatly. Hessian-based multiscale filtering has been proposed in a number of vessel enhancement approaches[8-11].One advantage of this approach in this category, is that vessels in a wide range of diameters can be captured due to the multiscale analysis. In this method, an input image is first convolved with the derivatives of a Gaussian at multiple scales and then the Hessian matrix is analyzed at each pixel in the resulting image to determine the local shape of the structures at that pixel. Krissian et al.[12] has specifically introduced several models of vessels and has used Hessian eigen values to define a set of candidate pixels which can be the centerlines of the vessels. For each of these candidates, pre-defined, multiscale response functions have been computed to determine the likelihood of the pixels corresponding to vessels of different scales. The drawbacks of the Hessian-based approaches are that they are highly sensitive to noise due to the second order derivatives and they tend to suppress junctions. Junction suppression leads to the discontinuity of the vessel network which is of course undesirable.

To deal with this problem, Agam et al.[13] proposed a filter model that is based on the correlation matrix of the regularized gradient vectors (first-order derivatives) to avoid the need for second-order derivatives. However when dealing with angiography images which are noisier and suffer from non-uniform illumination, it share the same limitations of Hessian-based filters in finding small and low-contrast vessels. In[14] a new framework proposed for the vessel enhancement filter utilizing the directional information present in an image. The proposed approach alleviates the calculation of the Hessian eigen values in a noisy environment. Specifically, the input image is first decomposed by a decimation-free directional filter bank (DDFB) into a set of directional images, each of which contains line-like features in a narrow directional range. The directional decomposition has two advantages. One is the noise in each directional image will be significantly reduced compared to that in the original one due to its omni-directional nature. The other is because a one-directional image contains only vessels with similar directions,this decomposition,filtering,recombination scheme also helps to preserve junctions.

Morteza Jalalat Vakilkandi et al. [15] proposed a new simple and fast fabrication of DDFB (called FDFB) without necessity of downsampling and resampling employed in DDFB, which is time consuming, especially if the directions are sizeable. it was shown that FDFB operates as well DDFB. FDFB is easy to implement, and faster than DDFB for angiography image analysis, but both suffer ringing artifacts. Smoothed FDFB has been used to enhance the coronary vessels in the angiograms. Directional Hessian based enhancement decreases noise effects his proposed framework enhances coronary vessel tree properly. This proposed morphological algorithm is effective to eliminate background non-vessel structures.

M. Sangeethal, S. Nirmala Devi and Dr. N. Kumaravel presented a novel method for automatic segmentation of blood vessel in coronary angiographic images[16].The proposed algorithm is composed of two steps, coronary angiogram enhancement process and entropy based thresholding. In the first step, a set of directional basis filters based on dyadic wavelet transform is designed to enhance blood vessels. Gaussian wavelet is used to fix the blood vessel directional information and its associated changes in coronary angiogram and a gradient image is obtained. Secondly the thresholding approach that evaluates 2-D entropy based on gray level gradient co-occurrence matrix is used to segment blood vessel from the background.

Cemal Köse and Cevat İkibaş introduced a model based segmentation method for extracting blood vessel structures in poor quality coronary angiograms[17]. This method extracts blood vessels in the angiograms by exploiting the spatial coherence existing in the image. Here, a circular sampling method is employed to exploit the coherence. This method uses a collection of 2D patterns to represent the 3D structures of vessels. The segmentation method employs the circular sampling method to produce the 2D slice samples at certain depths on each pixel on a varying background on the image, so several 2D sample slices of the 3D pattern of blood vessels are collected. These 2D slices are compared with certain original patterns in order to check whether a slice is part of a blood vessel. This method exploits the spatial coherency existing in two dimensional medical images and works on pixels on the image for extracting the structure of blood vessels. This automatic segmentation method is robust to overcome noise, low contrast and varying background, and able to extract vascular structure without human intervention. To eliminate small noisy parts and fragments at the final image, a circular filtering method is used and quality of segmentation is improved.

Kaiqiong Sun, Shaofeng Jiang and Yu Wang obtained the important information of the shape and the location of the coronary artery tree by the fuzzy morphological operations and watershed[18]. After the enhancement of image with the traditional morphological top-hat operator, the vessel image is filtered with the fuzzy morphological opening with a set of linear structuring elements at different orientation. At the same time, the enhanced image is also filtered with the dual of fuzzy opening with the same structuring elements set. The two filtered vessel image is then combined into a new image considering the local orientation consistency, detected by the morphological filter, within a linear neighborhood of each location. Threshold of the result image produces the binary vessel structure which is separate from background structure. The extracted vessel structure is lastly treated as prior of shape and location of vessel and used as marker in morphological watershed for detecting the accurate vessel boundaries. Though the fuzzy morphological operation proposed can character the vessel structure under many circumstances, more dedicated model or operation are still needed to group this description for robust and integrated vessel segmentation.

Shoujun Zhou et al. presents a novel tracking method for automatic segmentation of coronary artery tree in the X-ray angiographic images, based on probabilitistic vessel tracking and structure pattern inferring[20]. The method is composed of two main steps, namely preprocessing, and tracking. In the preprocessing step, multiscale Gabor filtering and Hessian matrix analysis are used to enhance and extract vessels from the original angiographic image, leading to a vessel feature map as well as a vessel direction map. In the tracking step, a probabilistic tracking operator is proposed to extract vessel segments or branches, together with a detector to identify vessel structure. The identified structure pattern is used to control the tracking process.

Hernandez-Vela et al. [21] presented a novel segmentation method for X-ray angiography images that takes into account vessel appearance, artery tree continuity, and borders appearance within Graph-cuts. They proposed a method based on multi-scale edgeness measure. Multi-scale edges and geodesic paths are combined to customize the Graph cuts model to the segmentation of vessel structures. Ashoorirad and Baghbani [22] used fuzzy inference system and morphology filters for vessel segmentation. These methods are difficult to deal with edge noises and bifurcations vessels. In contrast, tracking based methods apply local operators on a region to estimate next vessel points. The algorithm is more efficient for segmentation of angiogram images and noise cancelling than other methods such as canny method.

Zhou et al. [23] presented a tracking method that utilizes vessel features to segment the vessel tree based on probabilistic tracking and fuzzy inferring. The tracking algorithm cannot effectively track vessels in complex background and mostly relay on the manual setting. Model-based methods such as deformable splines and snake models use a set of parametric curves to segment. Sun et al. [24] proposed an active contour model using local morphology fitting for automatic vascular segmentation. The model based methods are hard to set model parameters and affect the computational cost for each frame of angiograms. Multi-scale Hessian matrix has been proposed to enhance and segment vessel structures [8,15,17]. For the enhancement of vessels, Frangi et al. [25] presented a multiscale method based on Hessian matrix. The local feature of the vessel which is based on the eigen values of the Hessian matrix is obtained. The eigen values can differentiate a pattern as tubular structure plate-like structure and blob-like structure. This method can enhance vessels effectively. By contrast, Tagizaheh et al. [26] presented an approach to vessel segmentation by combining multi-scale Hessian matrix and active contour model.

Zulong Yu and Kaiqiong Sun presents an approach for the extraction of vessel on angiogram by using morphology feature driven deformable model[27].They proposed a vessel segmentation method based on region based active contour in which the morphology measure of regions acts as stop criterion of curve instead of gray intensity or its gradient and therefore the problem caused by gray intensity inhomogeneity is avoided. Faten M'hiri proposed a segmentation framework to extract tubular structures from x-ray angiographies[28].The framework first enhances tubular structures by a vesselness filter. Then, the structures are segmented by the proposed adaptive active contour method which combines a local and global fitting energy. Those two forces are weighted according to the image's homogeneity value. Due to the combination of local and global forces, the proposed system is robust to noise and intensity inhomogeneity.

Shan Wang et al. proposed an efficient method for segmentation of angiograms which combines multi-filtering based on Hessian matrix and region-growing[29]. This method is particularly effective for noise suppression and the extraction of small and distal vessels. The multi-seed region-growing algorithm can reduce computation time observably, and also make much contribution to connect the discontinuous vessels and detect the small and distal vessels. Wenwei Kang 1, Wenying Kang2 and Yang Li proposes a novel approach on the basis of degree-based fusion algorithm for coronary angiograms[30]. At first, the same original image is enhanced by using two different segmentation methods. Secondly, coronary arteries are extracted from two enhanced images through the degree method. Finally, two extracted vessel images are fused.

Faten M'hiri, Luc Duong, Christian Desrosier and Mohamed Cheriet proposed a novel interactive method to segment vascular structures by combining Hessian-based vesselness information and the random walk formulation, in which manually selected seed points can be used to refine the segmentation result [31].This method extends the Random Walker formulation by integrating vesselness information. Ying-Che Tsai, Hsi-Jian Lee and Michael Yu-Chih Chen proposed a effective method for the vessel segmentation based on Hessian matrix[32]. Firstly to obtain vessel structure more reliably, they selected 25 frames of well-contrast angiograms automatically for further vessel segmentation. Secondly, they defined an adaptive feature transform function using the gray value and the scale to improve the feature response. In the part of the segmentation, a new adaptive vessel feature function is defined to extract the vesselness feature map. Compared to other methods, it is easier to control and more robust in complex background.

III.CONCLUSION

In this article, both early and recent literature related to coronary vessel segmentation algorithms and techniques are covered. Here the current segmentation techniques are introduced which will provide a framework for the existing research. This will help to improve the accuracy of segmentation of coronary angiogram in future.

REFERENCES

[1] World Health Organization,"Cardiovascular diseases (cvds), fact sheet n317," September 2012.

[2] R. Poli and G. Valli, "An algorithm for real-time vessel enhancement and detection", Comp.Methods and Prog. in Biomed., vol. 52, pp. 1–22, January 1997.

[3] Wilkinson M., Westenberg M. Proc. Int. Conf. on Medical Image Computing and Computer-Assisted Intervention, LNCS. Vol. 2208. Utrecht, The Netherlands: 2001. Shape preserving filament enhancement filtering; pp. 770–7.

[4] Eiho S., Qian Y. Detection of coronary artery tree using morphological operator. Proc. IEEE Comput. Cardiol. 1997:525–8.

[5] Zana F., Klein J. C. Segmentation of vessel-like patterns using mathematical morphology and curvature evaluation. IEEE Transaction on Image Processing. 2001;10:1010–9.

[6] Krissian K. Flux-based anisotropic diffusion applied to enhancement of 3-D angiogram. IEEE Trans Med Imaging. 2002;21:1440–2.

[7] Orkisz M., Bresson C., Magnin I., Champin O., Douek P. Improved vessel visualization in MR angiography by nonlinear anisotropic filtering. Magn Reson Med. 1997;37:914–9.

[8] Frangi A., Niessen W., Vincken K., Viergever M. Multiscale vessel enhancement filtering, in: Medical Image Computing Computer-Assisted Intervention. Lecture Notes Comput Sci. 1998;1496:130–7.

[9] Frangi A., Niessen W., Hoogeveen R., van Walsum T., Viergever M. Model based quantitation of 3-D magnetic resonance angiographic images. IEEE Trans Med Imaging. 1999;18:946–56.

[10] Frangi A., Niessen W., Nederkoorn P., Bakker J., Mali W., Viergever M. Quantitative analysis of vascular morphology from 3D MR angiograms: *In vitro* and *in vivo* results. Magn Reson Med. 2001;45:311–22.

[11] Shikata H., Hoffman E.A., Sonka M. Proc. SPIE Int. Symp. Medical Imaging. Vol. 5369. San Diego, CA: 2004. Automated segmentation of pulmonary vascular tree from 3D CT images; pp. 107–16.

[12] Krissian K., Malandain G., Ayache N., Vaillant R., Trousset Y. Model-based detection of tubular structures in 3D images. Comput Vis Image Underst. 2000;80:130–71.

[13] Agam G., Armato S. G., Wu C. Vessel tree reconstruction in thoracic CT scans with application to nodule detection. IEEE Trans Med Imaging. 2005;24:486–99

[14] Y. Xu, H. Zhang, H. Li and G. Hu, "An improved algorithm for vessel centerline tracking in coronary angiograms", Computer Methods and Programs in Biomedicine, vol. 88, no. 2, pp. 131-143,November 2007.

[15] Morteza Jalalat Vakilkandi, Mohammad Reza Ahmadzadeh, Rasoul Amirfattahi and Saeid Sadri1."Accurate Coronary Vessel Extraction Using Fast Directional Filter Bank" IEEE conference on Machine Vision and Image Processing (MVIP), 2011

[16] M. Sangeethal, S. Nirmala Devi, Dr. N. Kumaravel," Wavelet Transform Based Coronary Blood Vessel Segmentation using Entropy Thresholding", IET 3rd International Conference On Advances in Medical, Signal and Information Processing, 2006. MEDSIP 2006.

[17] Cemal Köse, and Cevat İkibaş," Segmentation of Coronary Vessel Structures in X-ray Angiogram Images by Using Spatial Pattern Matching Method", 23rd International Symposium on Computer and Information Sciences, IEEE 2008. ISCIS '08.

[18] Kaiqiong Sun, Shaofeng Jiang and Yu Wang "Segmentation of Coronary Artery on Angiogram by Combined Morphological Operations and Watershed" 2nd International Conference on Biomedical Engineering and Informatics, IEEE2009. BMEI '09.

[19] Truc P. T., Khan M. A., Lee Y. K., Lee S., Kim T.S. Vessel enhancement filter using directional filter bank.Comput Vis Image Underst. 2009;113:101–12.

[20] Shoujun Zhou, Wufan Chen, Zhengbo Zhang and Jian Yang," Automatic Segmentation of Coronary Angiograms Based on Probabilistic Tracking", IEEE conference on Bioinformatics and Biomedical Engineering , 2009.

[21] A. Hernández-Vela, C. Gatta, S. Escalera, L. Igual, V. Martín-Yuste, M. Sabaté, P. Radeva, "Accurate coronary centerline extraction, caliber estimation and catheter detection in angiographies", IEEE Transactions on Information Technology in Biomedicine, vol. 16, no.6, pp. 1332-1340, 2012.

[22] M. Ashoorirad and R. Baghbani, "Blood vessel segmentation in angiograms using fuzzy inference system and mathematical morphology", International Conference on Signal Processing Systems, pp. 272-276, May 2009.

[23] Shoujun Zhou, W.Chen, Z.Zhang and J. Yang," Automatic Segmentation of Coronary Angiograms Based on Probabilistic Tracking" 3rd International Conference on Bioinformatics and Biomedical Engineering , 2009. ICBBE 2009.

[24] K. Sun, Z. Chen, and S. Jiang, "Local morphology fitting active contour for automatic vascular segmentation", IEEE Transactions on Biomedical Engineering, vol. 59, no. 2, pp. 464-473, February 2012.

[25] A.F.Frangi, W.J.Niessen, K. L. Vincken, and M.A.Viergever, "Multiscale vessel enhancement filtering", Medical Image Computing and Computer-Assisted Intervention , vol. 1496, no. 3, pp.130–137,October 1998.

[26] M. Tagizaheh, S. Sadri and A. M. Doosthoseini, "Segmentation of coronary vessels by combining the detection of centerlines and active contour model", Machines Vision and Image Processing, November 2011.

[27] Zulong Yu and Kaiqiong Sun," Vessel Segmentation on Angiogram using Morphology Driven Deformable Model" IEEE 2010 3rd International Conference on Biomedical Engineering and Informatics (BMEI 2010).

[28] Faten M'hiri , Ngan Le T. Hoang , Luc Duong and Mohamed Cheriet ,"A new adaptive framework for tubular structures segmentation in X-ray angiography".The 11th International conference on information sciences, signal processing and their applications: main tracks IEEE2012.

[29] Shan Wang, Bonian Liand Shoujun Zhou "A Segmentation method of Coronary Angiograms based on Multi-scale Filtering and Region-Growing" International Conference on Biomedical Engineering and Biotechnology 2012,IEEE Computer society.

[30] Wenwei Kang 1, Wenying Kang2 and Yang Li" The Segmentation Method of Degree-based Fusion Algorithm for Coronary Angiograms" 2nd International Conference on Measurement, Information and Control IEEE 2013.

[31] Faten M'hiri, Luc Duong, Christian Desrosiers, Mohamed Cheriet,"Vesselwalker : coronary arteries segmentation using random walks And Hessian-based vesselness filter" IEEE 10th International Symposium on Biomedical Imaging ,2013.

[32] Ying-Che Tsai, Hsi-Jian Lee and Michael Yu-Chih Chen," Adaptive Segmentation of Vessels from Coronary Angiograms Using Multi-scale Filtering",International Conference on Signal-Image Technology & Internet-Based Systems, IEEE 2013.