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Overlapping Coronary Vessels in Angiography- A Review

Mahmood Mohammed Ali Omar[1,2] Rahmita Wirza O.K. Rahmat[1] Puteri Suhaiza Binti Sulaiman[1] Hizmawati Binti Madzin[1] Sazzli Kasim[3,4]

[1] Faculty of Computer Science and Information Technology, University Putra Malaysia, Malaysia

[2] Ministry of Higher Education and Scientific Research, Inspector General Office, Iraq

[3] Faculty of Medicine, University Teknologi MARA, Malaysia

[4]I-PPerForM, Universiti Teknologi MARA, Malaysia

Mahmood_022004@yahoo.com

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Abstract

coronary heart disease remains affects millions of people around the world. X-Ray angiography imaging is a vital tool in assisting cardiologist for real-time visual analysis of coronary artery vessels to diagnose coronary artery disease. However, this tool only able to give cardiologist with less information because its 2D output and may suffer from overlapping coronary artery. Overlapping of the coronary artery vessel in the X-Ray angiography image is one of the issues can affect the result of segmentation angiography image and reconstruction techniques. Many publications might be found in the literature that presents the problem of overlapping coronary artery vessel in the X-Ray angiography image. However, to the best of our knowledge, there is not any review or survey confirmation of this problem in one paper. In this paper, we survey those papers that mention the overlapping coronary artery's problem in X-Ray angiography image collected from C-arm, with respect to the purpose of usage of the X-Ray angiography image. Coronary artery segmentation is the process of extract vessels from 2D angiography image but the output of this process also have difficulty to overcome the problem of overlapping coronary artery vessel in the X-Ray angiography image. Therefore, it is becoming more important to propose an algorithm that can accurately separate overlapping vessels segments.

Keywords: **medical image processing; x-ray angiography images; vessel overlap; coronary artery.**

1. Introduction

Ischemic heart disease remains the number one killer globally. Treatment utilizing coronary angiogram is integral in assessing patients. Although angiography images generally have some limitations, such as a low contrast, a poor signal-to-noise ratio, and vessel overlap, the usage of X-ray angiography images by cardiologists is in increase. The increasing usage of coronary X-ray angiography by cardiologists come from its ability to deal with the diagnosis and treatment ways in real-time. Projection of a 2D image into a 3D structure may allow a better understanding of diseases for both patients and physicians providing them with more awareness and knowledge. Whole vessel structures may not be accurately acquired from 2D x-ray angiograms by clinicians because of limitations of x-rays, such as vessel overlapping and foreshortening vessels (Xiao et al., 2016), (Auricchio, Conti, Ferrazzano, & Sgueglia, 2014), (Liu, Hou, Hao, & Qin, 2014), (Liu, Hou, Li, Hao, & Qin, 2013). Fig. 1. illustrate coronary vessel overlap in 2D x-ray angiogram image. Coronary artery segmentation is the process of segment vessels from 2D angiography image but the output of this process also have suffered to overcome the problem of overlapping coronary artery vessel in the X-Ray angiography image. Separation of overlapping vessels is important for vessel segmentation and 3D reconstruction. Two groups of papers illustrate the coronary vessel overlapping problem which are segmentation and reconstruction papers.

This paper organized in five sections; Section 2 represent the segmentation angiogram images. Coronary artery reconstruction angiogram images represent in Section 3. The conclusions of papers are given in section 4. Lastly, the short summary and future works delineated in Section 5.

2. Segmentation Angiogram Images

Segmentation of coronary artery from angiography images is a first and essential step for angiography image processing which some of them involve coronary artery registration and 3D reconstruction in the angiogram. Furthermore, the result of segmentation could be very useful for physicians to check coronary arteries. However, vessel segmentation methods such as (Blondel & Ayache, 2006) (Sato, Araki, Hanayama, Naito, & Tamura, 1998) (Wink, Kemkers, Chen, & Carroll, 2003) (Cetin & Iskurt, 2016) segment angiograms that contain overlapping vessel as one vessel as illustrate in Fig. 2. However, several proposed vessel segmentation methods (S. J. Chen & Carroll, 2010) (Movassaghi, Rasche, Grass, Viergever, & Niessen, 2004) (Haris et al., 1999) (Parker et al., 1990), didn't take into account the

angiograms that contain vessel overlap or with minimal vessel overlap. Others (Khaleel, Rahmat, Zamrin, & Mahmod, 2012) (Tayebi et al., 2014), take into account but the result was segment both of vessels as one part. Overlapping and foreshortening of coronary artery are:

1) effect on the qualitative analysis of coronary diseases and only the physician's experience could be corrected it (Goyal, Yang, & Prakashagrawal, 2013) (Yang, Wang, Liu, Tang, & Chen, 2009) (Andriotis et al., 2008).
2) set up significant restrictions on the x-ray imaging technologies that limiting the automatic estimation of coronary artery disease (Medina, Wahle, & Mark, 2002) (Christiaens, Van de Walle, Gheeraert, Taeymans, & Lemahieu, 2001).

3. Reconstruction Angiogram Images.

With the increase of doctors that rely on 3-D reconstruction to visualize coronary arteries, a lot of research works achieved recently. However, the research works are not well suited to work in real-time and they are not accessible in clinical routines. As mentioned before, segmentation of coronary artery from angiography images is a first and essential step for angiography image processing like 3D reconstruction of coronary artery tree vessels.

In reconstruction methods such as (Liu et al., 2014) (S. Y. J. Chen, Carroll, & Messenger, 2002) also segment angiograms that contain overlapping vessel as one vessel as illustrate in Fig. 2. Whereas cardiologist takes angiograms with ideal viewing angles to avoid overlap and vessel shortening as show in Fig. 3.

Most published studies avoid choosing images with overlapping vessels in performing the 3D-reconstruction process (Movassaghi et al., 2004) (S. J. Chen & Carroll, 2010). Brost et al. used a phantom vessel with minimal overlap when acquired X-ray projections from various viewing angles (Brost et al., 2009). To change the center line identified vessel points and related vessel cross-sectional diameters, an interactive editing tool used if values of vessel features are not calculated correctly because of overlapping vessels or a noisy background (S. J. Chen & Carroll, 2010). It is very difficult to accurately reconstruct overlapping vessel segments (Cong et al., 2016) (Omar et al., 2017) automatically or semi-automatically with current reconstruction methods (Zheng, Meiying, & Jian, 2010). Therefore, it is becoming increasingly important to propose an algorithm that can accurately separate the overlapped vessels segment.

4. Conclusions.

To the best of our knowledge, very few publications might be found in the literature that discusses the issue of the overlapping vessel. Guo et al. proposed to solve this issue by tracing the skeleton (Guo, Chen, Lee, & Tsai, 1998). Xu et al. mention that tracking-based algorithms have difficulties in coping, diameter and arterial overlapping (Xu, Zhang, Li, & Hu, 2007). Traditional tracking based segmentation approaches cannot work efficiently because of bifurcation or vessel overlapping (Cong et al., 2016). However, tracking based segmentation has difficulty to overcome with some situations such as arterial overlapping as (Greenspan, Laifenfeld, Einav, & Barnea, 2001) (Xu et al., 2007) mentioned with situations such as sudden changes in the center line's orientation, diameter and arterial overlapping (Xu et al., 2007). In the future, we plan to enhance ability of coronary artery segmentation methods from angiogram by propose a post processing method to solving the problem of overlapping vessel in segmentation results to get segment of coronary arteries in X-ray angiography images without avoiding angiograms that contain overlapping vessels.

5. Summary.

From the literature about the vessel-overlapping problem, we observed that this issue has been mention widely and not solved yet as well. However, many researchers avoid choosing images with the overlapping vessel in implementation 3D reconstruction. In addition, cardiologist takes angiograms with ideal viewing angles to avoid vessel overlap and shortening. Therefore, it is becoming increasingly important to propose an algorithm that can accurately separate overlapped vessels segments to solve this issue. Table 1 below summarizes of literature shows the issue of overlapping coronary artery vessel.

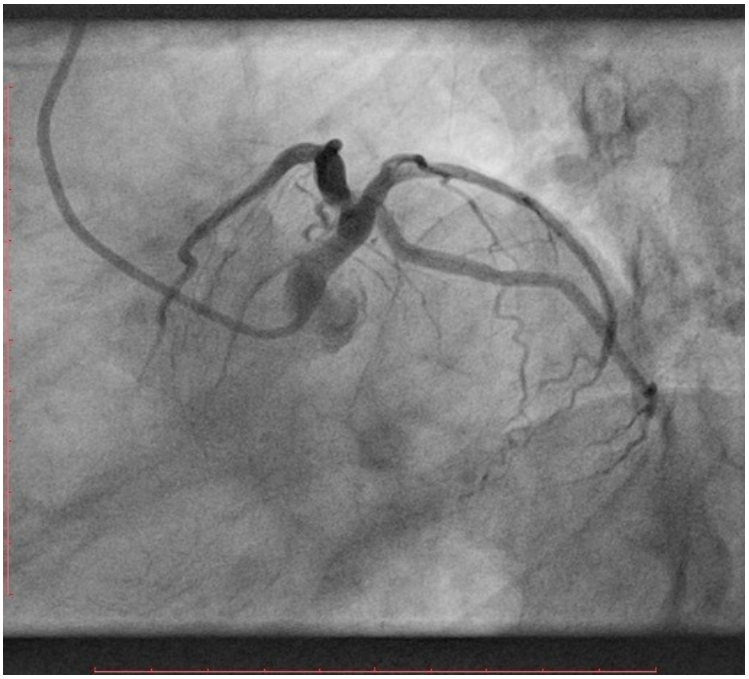

Figure 1. coronary vessel overlap in 2D x-ray angiogram image.

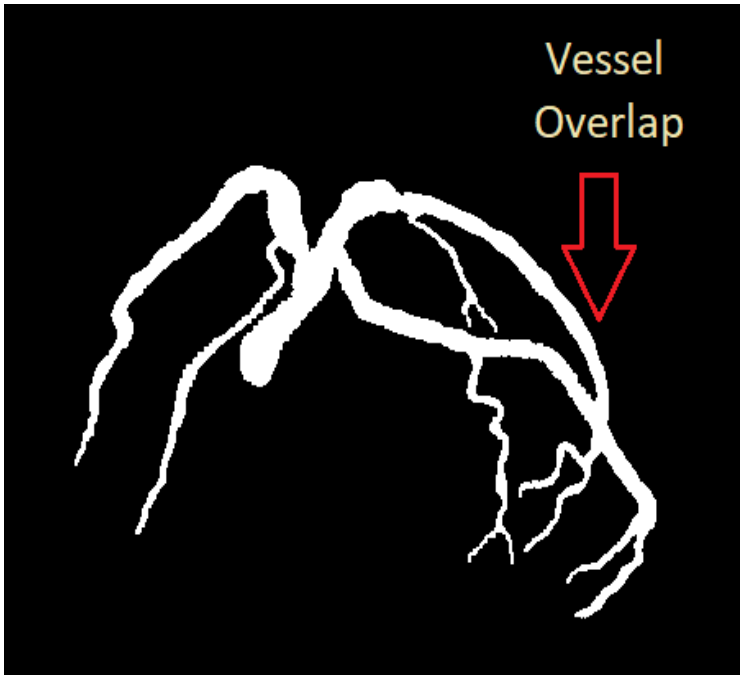

Figure 1. overlap vessel after segmentation.

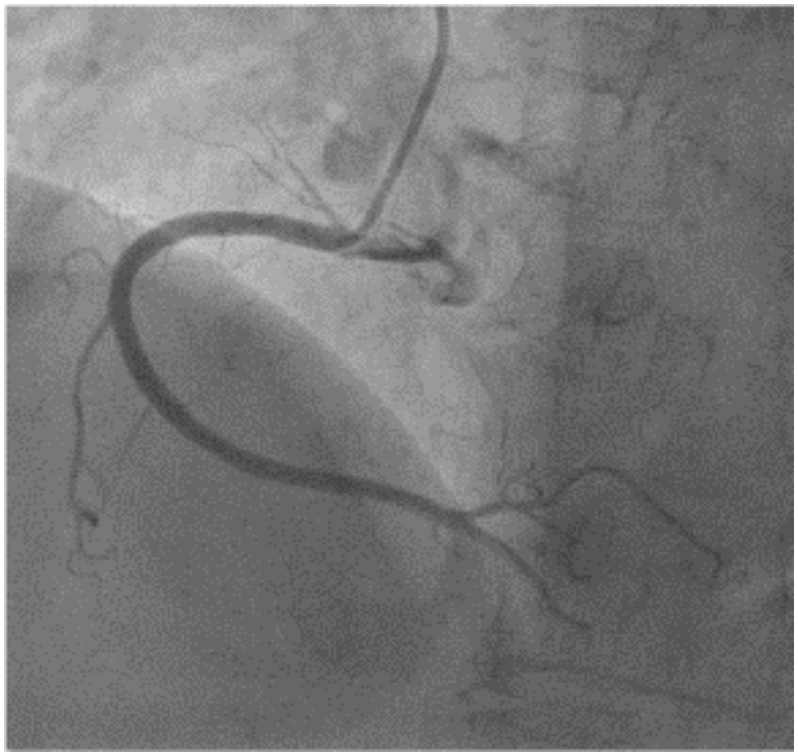

Figure 3. angiograms with ideal viewing angles to avoid overlap vessel.

uthor	Techniques	Issues and problems
lovassaghi. et al. (2004) & en and Carroll et al. (2010) & Haris et al. 999) Liu et al. (201 & Parker et al. 1990	3D vessel reconstruction	Avoid choosing images with overlapping vessel or with minimal vessel overlap
ost et al . (2009)	Acquired X-ray projections from various viewing angles	Used a phantom vessel with minimal overlap
aleel et al. (2012 Tayebi et al. 014)	Vessel segmentation	The result was segmented both of vessels as one part.
ai et al. (2015) & et al (2007)	Tracking based segmentation	Tracking cannot work efficiently because of bifurcation or vessel overlapping
ben et al. (2015)	Fusion between intravascular ultrasound and biplane angiography	Overlapping limited the automatic estimation of coronary artery disease
oyal et al. (2013) & ristiaens et al. 2001	A Survey	Overlapping and foreshortening effect on qualitative analysis of coronary diseases and can be corrected only by the experience of the physician.
ng et al. (2009) & driotis et al. (200 ; Chen, Carroll, and essenger (2002)	3D vessel reconstruction	
rdinando et al. (20	Generate 3D meshes of coronary bifurcations from a pair of planar angiographic images	Overlap and foreshortening limited traditional X-ray angiography technique
ao et al. (2016) & et al. (2014) & iu et al. (2013)	3D vessel reconstruction	Overlap and foreshortening limited traditional X-ray angiography technique
uo et al. (1998)	3D Reconstruction of Brain Blood Vessels by tracing the skeleton,	It can be unreliable, tedious. Hanger et al. (2002)
eng et al. (2010) & ng et al. 2016 & mar et al. (2017)	3D vessel reconstruction	It is very difficult to accurately reconstruct overlapping vessel segments automatically or semi-automatically with current reconstruction methods

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