**Abstract**

**What is TAVI? Why the tracking of aortic valve plane? Why the tracking of calcification? Contributions? Results?**

Transcatheter aortic valve implantation(TAVI) is a therapeutic alternative for high-surgical-risk patients with severe symptomatic aortic stenosis. Because the aortic root cannot be observed directly by the surgeon during aortic valve replacement, 2-D X-ray angiographic and fluoroscopic images are typically used to guide TAVI procedures, for which contrast agent needs to be injected from time to time to make the anatomy of the aortic root visible under X-ray. Exact valve placement is crucial during the intervention, also, the contrast of fluoroscopic images is generally limited to minimized the radiation exposure for the patient and the physician. Advanced visualization and augmented reality involving patient-specific 3-D models of the aorta can greatly facilitate the relatively complex TAVI procedures by providing a more realistic anatomy of the aortic root. In this paper, we propose a new method based on the *Tracking-Learning-Detection* approach, applied to the aortic valve calcifications in order to determine the position of the aortic valve plane and 2-D/3-D fusion in intra-operative TAVI images. The proposed method includes three main steps: *In Initialization step*, the oriented bounding box of calcification is manually initialized in order to define the distance between the calcification of interest and the aortic valve plane (AVP) in one chosen frame; *Tracking of Calcification* to determine the position of the calcification in each frame of the live sequence; *Updating of the AVP* to depict the overlaid AVP and 3-D aortic root mesh onto 2-D fluoroscopic images without contrast injections. The approach was evaluated on 25 TAVI procedures that contain angiographic and fluoroscopic imaging as well. Edwards SAPIEN and CoreValve were implanted in 12 and 33.33% of patients, respectively. The TAVI approaches used were transarterial (transfemoral: 66%; subclavian: 5%) or transapical in 29%. Tracking success rate was 68.3%. Providing an absolute mean displacement error less than 10 pixels (≈2mm), the early results are satisfactory in terms of feasibility. Its suitability for the TAVI procedure has been also analyzed.

**Introduction**

Affecting 1.8% of the global population, aortic stenosis is the most common valvular lesion occurring among elderly patients and has become extremely frequent because of changing demographics in industrialized countries. There are about 60,000 surgical aortic valve replacements every year in Europe and even more in the United States [1]. For people who have significant aortic stenosis, the only really effective treatment is to surgically replace the diseased aortic valve with an artificial valve. Unfortunately, the standard method of aortic valve replacement requires a major open-heart surgical procedure, and, especially in the elderly patients who most typically develop aortic stenosis, it is a procedure that carries significant risk. Transcatheter aortic valve implantation (TAVI) has emerged as a promising alternative to conventional aortic valve replacement for elderly patients with severe, symptomatic aortic stenosis who are otherwise left untreated due to the perceived high risk of operative mortality. Compared to the standard aortic valve replacement surgery, TAVI offers a replacement valve introduced through an artery via a small incision (usually the femoral artery) or, less often, surgically with an incision into the chest and then into the left ventricular apex (the transapical approach). About the transfemoral artery procedure that is the most common used, after catheterization through a femoral access, the overall procedure consists in introducing the transcatheter valve passing through successively the descending aorta, the ascending aorta and the native valve to finally perform the deployment of the aortic valve bioprosthesis. For both access types, the last stages concerning the localization and the deployment of the valve need the development of efficient tools to make more secure and reliable the TAVI procedure.

During TAVI procedures, X-ray angiographic and fluoroscopic imaging is routinely used to guide the operation, because the visibility of the target area is limited to the naked eyes due to the small incisions. However, fluoroscopic images do not display the anatomic structures without the contrast agent, which on the other hand needs to be minimized for patients’ and physicians' safety. Determining exactly valve location and minimizing the use of contrast injections are urgently needed during the surgical intervention, because complications can arise from a misplaced valve [2]. The objective is thus to develop efficient tools coping with difficulties in obtaining an optimal view of the native valve to define then an optimal target location. Only few previous studies deal with intra-operative support for TAVI procedure.

(Related works)

About the Aortic Valve Plane (AVP) tracking, Wijesinghe N. et al. [3] have previously proposed a system to track the AVP in fluoroscopic image sequences. This method requires two standard imaging views performed by conventional cine-angiography for initialization step.

Previously, in [4], an intra-operative guidance system has been proposed by Karar M.E. et al. to include the planning system of [5] and to perform real-time tracking of the aortic prosthesis in fluoroscopic images. A system for automatic segmentation and for the static overlay of aortic root volume and landmarks on live fluoroscopic images is described in [6][7][8]. Using intra-operative MRI guidance, a new robotic assistance system has been evaluated for delivering the AVP using a phantom [9].

Recently, Karar M.E. et al. [10] have proposed a method includes a dynamic overlay of an intra-operative 3-D aortic root mesh model and an estimated target area of valve implantation onto live 2-D fluoroscopic images. However, this is based on a template-based tracking procedure of a pigtail catheter which moves in accordance with the aortic root only when this catheter is locked in one of the native valve's cusp. Thus, user-interaction is required to initialize the algorithm and to correct fluoroscopy overlay errors during the intervention.

(Compared with previous work)

Compared with previous work, our method focuses on tracking of AVP and 3-D aortic root mesh in a intra-operative sequence of images rather than overlay of the preoperative 3-D data in a single contrast-enhanced frame. Also, in our approach, only one imaging view is required for interactive initialization. Lastly, a thorough accuracy analysis of the method has been performed with manual tracings as reference standard. This gives a clear indication of algorithm accuracy for, e.g., applications as prosthesis navigation and prosthesis deployment.

This paper is organized as follows. ...

**Method**

(The annular plane is sometimes visible depending on the amount of annular calcification, but often only indirect clues are provided by the position of a pigtail catheter. The pigtail catheter should be placed at the bottom of a coronary sinus.)

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