Automatic 3D Ultrasound Diastolic Mitral Valve Segmentation With Signal Dropout Correction

Wenyao Xia
Supervisor: Dr. Terry Peters

Introduction:
Moderate to severe valvular disease is estimated to affect 2.5% of the general population with mitral valve (MV) regurgitation being the most prevalent form of the disease. However, due to the complexity of mitral valve repair, almost one-third of patients develop recurrent moderate or severe mitral regurgitation (MR). This has motivated our research group, the VASST lab at Robarts Research Institute, to develop patient- or pathology-specific models for pre-operative planning and training for MV repairs.

Objective:
In order to produce an accurate and representative physical model, it is crucial to first establish a virtual model using image segmentation technique based on patient Transesophageal Echocardiography (TEE) data. However, due to the nature of ultrasound imaging, the obtained images are very noisy and often suffer from severe signal dropout, which affects the segmentation accuracy significantly. In this study, we propose a more robust algorithm for mitral valve segmentation on ultrasound images, which detects and corrects local signal dropout on leaflet regions.

Methods:
First, we combined the existing state-of-the-art approaches by using the segmentation result obtained from continuous max flow (CMF) graph cut as the initialization for the active contour method. Then, a novel spatial coherence constraint was imposed to correct possible mis-segmentation due to corrupted images and signal dropout. The spatial coherence constraint was primarily based on the number of disconnected components from the segmentation binary map. Since the spatial coherence constraint was not differentiable, we also proposed a real-time solution to find the approximated solution.

Results:
As shown in the figure below, the proposed method demonstrated superior performance over the existing segmentation algorithms. The proposed algorithm was able to detect regions affected by signal dropout and correct the segmentation results based on neighboring slides. This improved the segmentation accuracy and eliminated holes on the mitral leaflets during 3D reconstruction with no significant increase to the computational time.

Conclusion:
In this study, we proposed a robust ultrasound image segmentation for the mitral valve. The proposed method requires minimum user interaction and has been demonstrated to be robust when applied to low quality images with heavy signal loss. The segmented volume was then 3D reconstructed and 3D printed as a physical dynamic mitral valve phantom. The phantom’s performance was compared and validated with real patient data with good resemblance.