Abstract

Real-time three-dimensional image guidance platform using transthoracic echocardiography and x-ray fluoroscopy

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Structural heart interventions (SHI) are a class of minimally invasive, catheter-based procedures that repair structural defects in the cardiac muscle, tissue, and valves through the insertion of corrective devices. Several SHI procedures rely on real-time image guidance from multiple imaging modalities for catheter navigation and device installation. X-ray fluoroscopy (XRF) is the primary modality for visualizing catheter devices, while echocardiography (echo) provides adjunct visualization of cardiac soft tissue structures and blood flow. In the present workflow, simultaneous interpretation of independent XRF and echo displays remains a challenge for the interventionalist. The purpose of this work was to develop a fully three-dimensional, minimally invasive, and real-time image guidance platform in which volumetric transthoracic echocardiography (TTE) is registered to 3D device reconstructions derived from biplane x-ray fluoroscopy. Development of this novel 3D TTE/XRF fusion platform was divided into three main tasks. First, a customizable multi-modality image phantom was designed and fabricated as a dedicated tool for evaluating 3D echo/x-ray co-registration performance. Second, a technique for tracking the 3D pose of a transthoracic probe based on the appearance of an attached fiducial apparatus in 2D x-ray imaging was devised. Third, a real-time fusion platform featuring an interactive 3D TTE/XRF display was implemented and characterized in phantom-based studies. With the multi-modality phantom, the platform achieved mean Target Registration Error (TRE) between 1.12 mm and 1.61 mm across a variety of clinically relevant TTE and XRF imaging

geometries, and 95% of registration errors for a given fluoroscopy sequence were within 1.77 mm. Computational processing performance was evaluated under conditions of probe, catheter, and valve motion on a single-GPU workstation. The platform was successfully implemented at frame rates of 7 – 8 frames-per-second with total system latencies ranging from 125 – 145 ms. This platform provides a co-registered and real-time 3D visualization of x-ray and echocardiography information that could be used to guide complex device navigation tasks during structural heart interventions.