Image Guidance and Semi-Autonomous Navigation for Robot Assisted Epicardial Interventions

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Objective

We are developing a software interface that is capable of adding semi-autonomous navigation to an existing robotic system with application to epicardial mapping and ablation. With semi-autonomous navigation, a surgeon or cardiologist can define paths along the epicardial surface for the robot to precisely follow, offloading some of the tediousness of certain procedures. Current MIS techniques (guided by fluoroscopy or intracardiac echo, for example) lack the situational awareness that is required to direct a surgical robot's motion along a prescribed path. Thus, to enable semi-autonomous navigation, we are introducing a new sensor-based image guidance framework for a fully representative visualization of the operating site.

Methods

The robot we are using is the CardioARM surgical snake robot, which combines the rigidity of a linear device with the maneuverability of a flexible device. For image guidance, we fuse preoperative imaging (from CT reconstruction) with an EM tracker mounted at the distal end of the robot to display a rendered 3D visualization of the operation. To improve image-guidance and to achieve situational awareness, we estimate the entire shape of the snake robot using historical EM tracker data and kinematic models of the robot. This estimation process uses a novel stochastic filtering algorithm that we developed for shape parameter estimation. Semi-autonomous path following is performed using a PID controller that automatically steers the robot along a path drawn on the epicardial surface via the graphical visualization interface.

Results

We have performed numerous semi-autonomous path following experiments on a bench-top cardiac phantom as well as 2 live trials on a porcine model. We have shown experimentally that our semi-autonomous path following algorithm is able to deliver the tip of the robot to within 2mm of the target end point of the prescribed path.

Conclusions

Our novel filtering method to achieve improved situational awareness has enabled accurate semi-autonomous navigation along a prescribed path on the epicardial surface. There are two improvements to this method that we are currently investigating: updating in real-time the patient-specific epicardial surface models to include motion parameters and modeling tissue compliance for improved situational awareness.