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Motion compensating catheter for beating heart surgery

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Technology description

Summary

MARKETS ADDRESSED:
To repair damage and defects within a heart, doctors currently use stopped-heart and open-chest surgeries. These procedures are highly invasive and incur a significant risk to the patient from neurological impairment to possible death. The technology covered by this invention provides a device for performing surgery within a heart while it is beating. This gives physicians a minimally invasive tool to perform structural repairs or electrophysiological procedures on a beating heart with the same accuracy as open-chest surgeries. This technology can non-invasively perform procedures with extreme accuracy, such procedures could include; atrial septal defect closures, mitral valve annuloplasty procedures, cardiac tissue resection or precision cardiac biopsies.

This technology allows one to perform surgery on a heart while it is in motion. The technology is embodied by a fast, motion compensating mechanical device that uses image guidance and a sophisticated software package to anticipate and react to the rapid movement of the cardiac tissue of interest. The device, which can either be in the form of a handheld tool or a standard cardiac catheter, allows a technician to perform very delicate surgeries such, such as mitral valve repair, without the need for heart stopping techniques. The technology takes advantage of real-time 3-D ultrasound images and a Radon transform-based algorithm for processing.

The system is composed of an actuated catheter module that is inserted inside the heart, a 3D ultrasound imaging system that views the catheter and the tissue of interest, and a visual servoing system that commands the mechanized device to follow a specific trajectory based on the 3D imaging information (See Fig. 1). The catheter module is inserted into the heart by the physician where it then braces itself against the heart structures while the end effector compensates for the motion of the moving tissue and applies a specific repair, such as stapling an implantable prosthesis or resecting tissue around a valve (Fig. 2, Left). 3D ultrasound imaging allows both the tissue and the catheter tool to be visualized and tracked at video frame rates in real-time (Fig. 2, right). The visual servoing system then extracts both the tool and tissue trajectory from this visual information and determines how the

catheter should be moved to compensate for the cardiac motion.

This technology offers a number of advantages over current heart repair approaches. First, this catheter-based approach allows for sophisticated heart repair to be performed without the considerable morbidities associated with large incisions in the chest, the use of the heart-lung bypass machine, or heavy sedation. This decrease in the invasiveness of these procedures will allow life-saving cardiac repair procedures to be expanded to a larger pool of potential patients who are too old or sick for a traditional open-heart procedure. Another benefit is that the system operates on a beating heart, thus enabling the clinician to evaluate the quality of the repair during the procedure. Finally, the system will save money on each procedure because they will take less time than traditional open-heart repair, the patient will have a shorter recovery time, and require less personal to complete.

This novel technology is a potential solution for heart valve repair, such as mitral valve annuloplasty, cardiac tissue resection, precision cardiac biopsies, cardiac electrophysiology procedures, and heart defect closures. All of these procedures could be improved or be made minimally invasive if performed with this technology. To reconfigure the system to perform a different procedure, only the catheter end effector needs to be replaced. The majority of the capital investment hardware can be shared among a range of procedures.

Fig. 1. The catheter system consists of a drive system, a catheter module, and a 3DUS visual servoing system. The system compensates for the fast motion of the cardiac tissue using 3D ultrasound imaging and visual servoing system to while the surgeon performs the repair procedure.

Fig. 2. Left: An illustration of the catheter braced inside the left atrium while operating on the mitral valve annulus. Right: Ultrasound image showing catheter, mitral valve annulus, and mitral valve leaflets.

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