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Active and Passive Compensation of Physiological Motion for Surgical Accuracy Enhancement

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Accuracy in surgical manipulation is impeded by physiological motion, including both heartbeat and respiratory motion of the patient and physiological hand tremor of the surgeon. The goal of enhancing accuracy in microsurgery while also minimizing cost and maximizing ease of use has motivated the development of a fully handheld instrument, known as Micron, which senses its own motion, estimates the undesired component of its movement, and provides active compensation by deflecting its tip to oppose the undesired component. Feedback sensing for control is provided by a purpose-built frequency-multiplexed optical tracker that provides six-degree-of-freedom tracking with noise of several microns at 2 kHz sampling. The instrument features a miniature 6-degree-of-freedom manipulator built into its tip. To enable vision-based control modes, the system is augmented with cameras viewing the workspace through the operating microscope. The talk will describe the design and operation of Micron, and will present experimental results from a variety of control modes including visual servoing and semi-automated scanning pattern generation.

Passive compensation of heartbeat and respiratory motion is the approach followed by HeartLander, an intrapericardial crawling robot that performs accurate epicardial interventions on the beating heart. The crawler adheres to the epicardium using suction, and moves via inchworm-like crawling, driven by flexible push-wires connected to motors outside the patient. Recent results with the system will be presented, including improving locomotion efficiency via synchronization with heartbeat and respiration, mapping and localization on the beating heart, and technologies for treatment by myocardial injection. Early steps in the development of HeartPrinter, a related system, will also be described.