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A Microsurgery-Specific End-Effector Equipped with a Bipolar Surgical Tool and Haptic Feedback

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Abstract : In tele-operative robotic surgery, an ideal haptic device should be equipped with an intuitive and smooth end-effector to cover the surgeon's hand/wrist degrees of freedom (DOF) and translate the hand joint motions to the end-effector of the remote manipulator with low effort and high level of comfort. This research introduces the design and development of a microsurgery-specific end-effector, a gimbal mechanism possessing 4 passive and 1 active DOFs, equipped with a bipolar forceps and haptic feedback. The robust gimbal structure is comprised of three light-weight links/joint, pitch, yaw, and roll, each consisting of low-friction support and a 2-channel accurate optical position sensor. The third link, which provides the tool roll, was specifically designed to grip the tool prongs and accommodate a low mass geared actuator together with a miniaturized capstan-rope mechanism. The actuator is able to generate delicate torques, using a threaded cylindrical capstan, to emulate the sense of pinch/coagulation during conventional microsurgery. While the tool left prong is fixed to the rolling link, the right prong bears a miniaturized drum sector with a large diameter to expand the force scale and resolution. The drum transmits the actuator output torque to the right prong and generates haptic force feedback at the tool level. The tool is also equipped with a hall-effect sensor and magnet bar installed vis-à-vis on the inner side of the two prongs to measure the tooltip distance and provide an analogue signal to the control system. We believe that such a haptic end-effector could significantly increase the accuracy of telerobotic surgery and help avoid high forces that are known to cause bleeding/injury.

Keywords : end-effector, force generation, haptic interface, robotic surgery, surgical tool, tele-operation
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