Bilateral Nonlinear Teleoperation for Flexible Link Surgical Robot with Vibration Control

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This paper addresses a new control scheme for bilateral telesurgical system with flexible links surgical robot. In this regard, hybrid structure of feedback and feedforward controller is suggested for flexible slave robot. This approach utilizes capability of Input Shaping (IS) as feedforward controller to reduce vibration at robot's end tip and the feedback controller based on collocated Proportional-Derivative (PD) for control rigid body motion of the system. Stability of closed loop input shaper for nonlinear systems is discussed for the first time in this article. The stability conditions for overall system with constant communication time delay are derived using lyapunov method. Due to the independence of the system parameters, combination of these controllers results stability robustness to parameter uncertainties. Moreover, It is shown that reshaped master command to slave's controller improves tracking performance in the presence of robot flexibility. Simulation results are used to verify the main theoretical points of this paper and demonstrate the effectiveness of proposed control framework in terms of input tracking and vibration suppression.