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6 DOF Cable-Driven Haptic Robot for Rendering High Axial Force with Low Off-Axis Impedance

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Abstract : This paper presents the design and mechanical model of a hybrid impedance/admittance haptic device optimized for applications, like bone drilling, spinal awl probe use, and other surgical techniques were high force is required in the tool-axial direction, and low impedance is needed in all other directions. The performance levels required cannot be satisfied by existing, off-the-shelf haptic devices. This design may allow critical improvements in simulator fidelity for surgery training. The device consists primarily of two low-mass (carbon fiber) plates with a rod passing through them. Collectively, the device provides 6 DOF. The rod slides through a bushing in the top plate and it is connected to the bottom plate with a universal joint, constrained to move in only 2 DOF, allowing axial torque display the user's hand. The two parallel plates are actuated and located by means of four cables pulled by motors. The forward kinematic equations are derived to ensure that the plates orientation remains constant. The corresponding equations are solved using the Newton-Raphson method. The static force/torque equations are also presented. Finally, we present the predicted distribution of location error, cables velocity, cable tension, force and torque for the device. These results and preliminary hardware fabrication indicate that this design may provide a revolutionary approach for haptic display of many surgical procedures by means of an architecture that allows arbitrary workspace scaling. Scaling of the height and width can be scaled arbitrarily.

Keywords : cable direct driven robot, haptics, parallel plates, bone drilling
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