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Disturbance Attenuation of a Handheld Parallel Robot

Ahmed El-Shenawy[1] Achim Wagner[2] Peter Pott[3] Ralf Gundling[4] MarKus Schwarz[4] Essam Badreddin[2]
ahmed.elshenawy@aast.edu achim.wagner@ziti.uni-heidelberg.de p.pott@emk.tu-darmstadt.de

Abstract—**Experimental results for a handheld six degrees of freedom parallel robot with realtime position control and disturbance attenuation are presented. The robot's base is freely movable in space by a human operator, while the tool is position controlled and stabilized relatively to a reference coordinate system. The challenge is to decouple the tool as far as possible from the user involved arm tremor and unintended motions. The robot is equipped with a camera-based position and orientation tracking system, linear actuators, and a realtime control system. Kinematics, co-ordinate transforms and work-space limits are presented with its specifications. Experiments with sinusoidal stimuli on a test stand and during the handheld operation are discussed with respect of stabilizing performance and work-space violation. The resulting error bounds of less than 0.5 mm in the Cartesian position demonstrate that such a robot device has the potential to improve the classical manual surgical interventions. Further, the paper demonstrates the compliance of the user motion to the workspace provided by the robot.**

tool platform) with respect to a moving bone of the patient (workpiece), while the complete machine is held in the surgeon's hand.

In literature, the hand's disturbances of a healthy human are described with frequencies up to 12 Hz [5]. While the amplitudes of the arm have a maximum drift of 8 mm/s without visual control [6] and 0.85 mm/s with visual control [7]. The patient motion due to breathing is in a range 0.25-0.5 Hz (depending on his age). For free hand milling operation with different tool trajectories a control with 6 DOF is needed. The 6 DOF movability can be provided by the kinematical modeling, which operates within a software controlled workspace. The required workspace is calculated according to a prototypical spine operation, where holes are drilled in and along the pedicles on the human spine. Thus, the selected workspace of the robot ranges from -20 mm to