Master-Slave Manipulator Performance for Various Dynamic Characteristics and Positioning Task Parameters

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Abstract

The performance of manually operated remote manipulators is limited by friction, tolerance of mating parts, limited speed of response, and other unavoidable factors which affect dynamic behavior. A review of the literature shows that little progress has been made towards describing or predicting these effects quantitatively. Such knowledge would be valuable both in understanding human motor behavior and in improving manipulator design. Single factor experiments were performed for a simple manipulator positioning task. The manipulator used was an experimental, two-degree-of-freedom, unilateral, master-slave manipulator. Microprocessor control of the dc electric torque motors which drive the joints enforced an approximately linear dynamic behavior of the arm throughout its range of motion. The characteristics of behavior which were studied were arm natural frequency, simulated Coulomb friction, and simulated backlash (deadband). The parameters of the positioning task which were varied were positioning accuracy and distance traveled. Performance was measured in task completion time. The data were analyzed statistically and regression coefficients obtained to explain the results in terms of information transmission concepts. In general, the information transmission rates were (0111'11 to differ for the gross motion (travel) and fine motion (Positioning) components of the task. For a well-trained subject and the best manipulator behavior, the two rates were the same, yielding the performance variations predicted by "Fitts' law." The variation in performance with manipulator characteristics and task parameters is explained in terms of operator strategies to minimize time within the error constraints by changing the point or transmission from fast gross motion to the slower and more conservative fine motion.

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