

Kinesthetic compensation for rotational misalignment of cameras used for teleoperation

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Kinesthetic feedback was shown to significantly improve the accuracy of teleoperations subject to rotational misalignments between the image source and the operator even without explicit training. Rotational misalignments are often encountered in teleoperation and telerobotics when a remote image sensor (usually a camera) is oriented so that the resulting display coordinates are rotated with respect to the coordinates in which the user is operating. In the past, users have had to learn to compensate for this misalignment through practice, camera adjustment, or the use of multiple camera images. A new compensation technique is proposed in which the hand not used for control is utilized to provide a kinesthetic cue to the camera orientation. This cue greatly reduces the difficulty operators have had in compensating for control-display misalignment. The cueing hand, which is positioned to copy the attitude of the viewing camera, provides a kinesthetic reference for the movement of other hand, which controls the teleoperated system. This enables users to make control movements relative to their kinesthetic sense of the orientation of their own (cueing) hand.

Experimental testing with single axis rotations was conducted to demonstrate the feasibility of this technique. Operators were required to make small (~2-3 cm) radial hand movements controlling a computer-displayed cursor under conditions of rotational misalignment with and without kinesthetic cues. Performance was measured by movement path length normalized to the path length each operator was able to achieve without misalignment. Even without explicit training, this kinesthetic cue reduced control inaccuracy associated with some rotational misalignments by as much as 64% (Figure 1). Although the kinesthetic cue clearly improved the accuracy of large movements, its benefit for small movements was particularly important, as these are more typical in control of NASA robot manipulators, such as the Orbiter Remote Manipulation System. Extension of the technique to multi-axis rotations is currently under way.