Human-Robot Interaction

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The design and control of robots for effective human interaction requires an understanding of the sensory and motor organization of the human half of the human-robot system. Below we describe three projects in haptic display and human augmentation robotics, in collaboration with faculty in psychology and biomedical engineering.

Fingertip Haptic Interface "Fingertip haptics" refers to the direct exploration of a virtual environment with the fingertips, rather than via an intermediate grasped object, such as a stylus or thimble. Because the fingertip is a rich sensory organ placed at the end of a sophisticated manipulative and sensory system—the hand and arm—there are many facets to fingertip haptic display. Among these, texture and temperature have been widely studied. Our current work focuses on two other sensations: slip and surface orientation. To date, we have shown that a slip display based on a rotating drum is able to recreate a strong sensation of moving one's finger across a smooth flat surface. We are now developing instrumentation that will let us examine the perceptual thresholds associated with slip velocity and direction as well as surface orientation. These data are to be the foundation of a new class of fingertip haptic displays now in the conceptualization stage.

Programmable Constraints for Rehabilitation and Assist Cobots use a computer-controlled rolling mechanism to make it possible to have simultaneously a high mechanical impedance in some directions and a low impedance in another direction—the feeling of a mechanical constraint, such as moving along a smooth rail, yet fully programmable. Under computer control, the cobot can exhibit a free mode as well. We are exploring the potential of cobots as a safe and inexpensive robotic solution to upper body stroke rehabilitation, as a cobot (Figure 2) allows natural reaching motions with a variable amount of path guidance.

Basic Human Motor Control Studies We are studying the use of programmable constraints for safe robot-assisted manipulation of heavy loads in materials handling, assembly, and construction. Frictionless constraints guide the load to the goal, allowing the human to choose force strategies which minimize the possibility of injury. To design programmable guides which increase productivity and safety, we are studying how humans naturally interact with constraints in tasks like turning a crank or pushing a load along a linear rail. Our studies have shown that subjects consistently apply forces against the constraint, even though these forces have no effect on the task. This implies the existence of force-direction preferences, depending on the body configuration. Without any detailed biomechanical modeling or psychophysical questioning, we have been able to derive this preference directly from data in a planar single-arm task (Figure 3).

Figure 1: Exploration of an object using a probe or stylus takes advantage of distal attribution—the ability for humans to easily extend their perception to the end of an implement. This approach, however, diminishes or eliminates access to basic surface features such as temperature, contour, and even certain aspects of texture.

Figure 2: A 2-dof cobot, which presents stiff yet smooth constraint paths to a human user grasping the handle. The wide, low design allows large constraint forces and a full range of human arm motion.

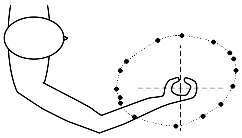

Figure 3: An experimental "iso-effort" force contour in the hand frame, derived directly from constraint force data.