Haptic feedback for robot-assisted surgery

Assistant Research Professor Mohsen Mahvash and Associate Professor Allison Okamura at the Engineering Research Center for Computer-Integrated Surgical Systems and Technology (ERC-CISST) have developed haptic feedback methods for teleoperated surgical-assistant robots. Haptic feedback can significantly enhance the performance of surgical-assistant robots, but current commercially available systems do not include significant haptic feedback to the operator. Through a collaboration with Intuitive Surgical Inc., haptic feedback has been tested on a version of the da Vinci Surgical System with customized software and hardware developed at ERC-CISST (Figure 1).

Teleoperated surgical-assistant robots consist of master manipulators and patient-side manipulators (Figure 2). A surgeon uses the master manipulators (typically one for each hand) to direct the patient-side manipulators to move surgical instruments to desired locations in the patient’s body. With haptic feedback, the surgeon can feel the interaction force between the patient-side manipulators and the patient’s body. Ideally, force sensors would be used to record the interaction forces, but the use of force sensors is limited in robot assisted surgery due to numerous practical considerations (including geometry, size, biocompatibility, sterilization, and cost.) Thus, we have developed haptic-feedback methods that do not require force sensors.

Each patient-side manipulator attempts to follow the motions of a master manipulator; haptic feedback can be provided to the surgeon when the master manipulators are also controlled to follow the patient-side manipulators. With a conventional controller, both the surgical environment forces and undesirable resistant forces of the manipulators (including friction and inertia forces) are transferred to the surgeon. We use feedforward controllers that estimate the resistant forces based on detailed dynamic models, in order to prevent the resistant forces from being fed back to the surgeon. A major challenge in designing the controllers is that, if the resistance forces of manipulators are overestimated (even on a rare occasion), the feedforward controller may lead the surgical robots to have unstable behaviors. We use passivity theory to ensure that the feedforward controllers never feed extra energy to the robots and never destabilize them.

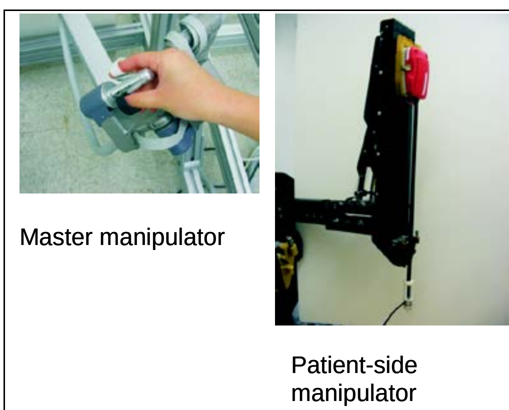
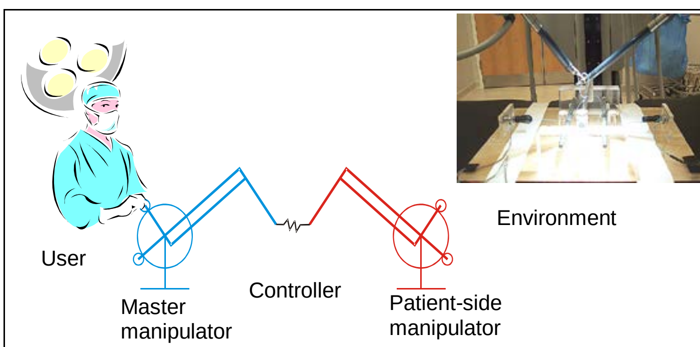


Figure 2: Custom da Vinci Surgical System



$$F_{\text{user}} = F_{\text{environment}} + F_{\text{friction}} + F_{\text{inertia}}$$

Figure 1: A haptic-feedback teleoperator