HAPTIC INTERFACE FOR SURGICAL MANIPULATOR

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Abstract
A surgical manipulator, the JHU/APL snake, intended for use in hip arthroscopy removal surgery has been developed. It is capable of translating, rotating, and bending and is currently controlled with a keyboard and mouse. This project concerns the successful development and implementation of two distinct interfaces for the manipulator using a PHANTOM® Premium haptic controller with the goal of increasing intuitiveness of control. The first interface allows the user to select a target position towards which the manipulator moves. The second allows the manipulator to continuously update the input position. We also discuss various enhancements to the base interfaces, including the use of force, audio, and visual feedback.

Significance
- Areas within pelvis are hard to reach during surgery; in manual procedures, there is less than 50% coverage of the cavity
- Dexterous manipulator allows for 85-95% coverage
  - But lacks an intuitive control interface and force feedback

Implementation
- Control the end-effector position, not individual joint angles
- Develop and implement simplified inverse kinematics model
- Primary Input: Position of PHANTOM haptic device
- Primary Output: Position of manipulator end-effector
- Force feedback using PHANTOM’s simulated spring force to indicate center of rotation
- C++ and MATLAB program run simultaneously to get input position and control manipulator, respectively

Approach: Interfaces
1. Keyboard Controller
   - Controls each degree of freedom separately using keystrokes/mouse
2. Point/Click
   - Since there are two paths to reach any target location (bend left or rotate right or rotate), program decides optimal path by that which precludes rotation of greater than 135°
3. Continuous

Approach: Feedback
1. Force Feedback
   - Spring force pulls PHANTOM stylus to current origin
2. Audio Feedback
   - Tone frequency proportional to deviation of cable forces from expected forces
3. Visual Feedback
   - Displays 3D position of tip

Approach: Task
- Touch manipulator tip to holes located at different heights on posts as quickly as possible in prescribed order
- In future, will use suspended hanging targets to protect manipulator tip/cables

Results
- Inexperienced user trials (IRB-approved) to measure speed, learning curve inconclusive
- Using qualitative feedback, interfaces were updated:
  - Direct PHANTOM-manipulator mapping for point/click mode
  - Decoupled rotation and translation for continuous mode
- Subsequent preliminary trials using the updated system with experienced users showed point/click to be fastest, followed by continuous control

Future Work
- Further inexperienced user trials using updated system
- Obtain qualitative feedback from surgeon
- More sophisticated 3D visualization
- Continued integration of sensory information with interfaces

What We Learned
- How to interface MATLAB and C++ via the MATLAB engine
- Simpler solutions may work effectively for given constraints
- Use stable system for subject trials

References

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