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Title: Algorithms for Haptic Rendering and Virtual Fixtures for Robotic Surgery

Abstract:

Haptic rendering is the application of forces in a virtual environment to a user interface (such as a flight control stick, haptic glove or surgical robot hand controls). The virtual environment can represent a physical environment. In the virtual environment, motions of the hand control device interact with a virtual representation of the physical environment, and kinesthetic feedback is provided to the user. When the physical environment includes a robot that is controlled by the user (or some other physical system that is under manual control), then haptic rendering facilitates co-robotic (human + robot) actions.

We have developed algorithms which perform haptic rendering of dynamically changing objects in real time, using one or more RGB-D cameras (such as the Microsoft Kinect). This allows for 'remote touching' of moving 3D physical objects. There are a wide variety of potential applications for this technology; any situation where an operator wishes to "feel" the boundaries (and possibly the surface) of an object at a distance, without the use of contact sensors. This provides an 'extra' channel for human machine interaction.

The motivating goal of this work is robotic surgery. The algorithms include methods to track surfaces of the physical objects and to avoid penetrating them. These algorithms can be used to define and enforce 'virtual fixtures'--that is, 'force fields' around objects, as perceived by the user through the haptic interface. These virtual fixtures can prevent motion of a surgical robot end effector into a prohibited area. Or they can provide resistance to the operator when entering protected areas (while still allowing entry). We anticipate that this will improve the precision and safety of robotic surgery, and perhaps shorten the time needed for some procedures. Virtual fixtures can be also used to guide tools (or the operator commands) along the surfaces of an object or along virtual surfaces at a specified distances from the object. This, combined with path planning, may also have applications in robotic surgery.