

Using Collaborative Haptics in Remote Surgical Training

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Abstract

We describe the design and trial of a remotely conducted surgical master class, using a haptic virtual environment. The instructor was located in the United States and the class was in Australia. The responses of the audience and participants are presented.

1. Background

Using haptics in remote collaboration has only recently been achieved in experimental situations, the major obstacle being feedback-induced instability. Kammermeier et al [2] state that haptic interaction implies a bilateral exchange of energy between the user and the environment. Communication delay (latency) can cause instability in remotely connected systems. Kim et al [3] achieved haptic collaboration across the Atlantic Ocean by introducing a predictive algorithm for collision detection, as well as three layers of damping. We have developed a specialized physics model [1] which can withstand latencies of around 200 milliseconds for surgical environments with soft objects. Such systems can therefore be shared across the globe.

2. Master Class Experiment

Our experiment extended this work with the aim of improving usability and including audience involvement. A broad-band internet connection was established between the class, in a conference auditorium in Canberra, Australia and the instructor at the Stanford University School of Medicine in California. Both used an immersive, hands-in, haptic environment (figure 1), high quality, multi-screen video and echo-free audio. The haptics were provided by a Sensable Technologies Phantom 1.5. The

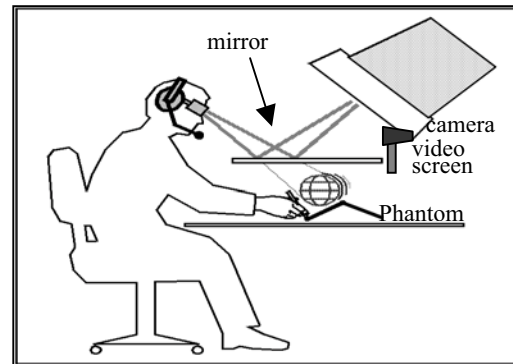


Fig. 1. The CSIRO haptic workbench

auditorium also had a 3D, passive-stereo projection screen for an audience of 70 medical professionals, 10 of whom participated in the haptic surgical instruction.

3. Application

The application involves a simulated gall bladder removal, with instructor and student working in the same virtual space on a 3D model of body organs. The organs can be touched, grasped and stretched simultaneously by both participants (figure 2). On each machine the deformed shape is duplicated, to give each user the ability to grasp the shape in its deformed state. Objects can be set with a mixture of elastic and plastic deformation properties and with variable pliability. Most organs are modeled with a surface mesh while sinuous organs such as the cystic duct are modeled with a spring-mass chain of connected segments. Haptic forces are calculated from the accumulated spring stretch. We were able to overcome latency-induced instability by calculating the physics on one machine only, and ignoring momentum and acceleration – objects either move under forces or stop when those forces are in balance. We also found that this mechanism allowed simultaneous manipulation with no need to lock objects for editing.

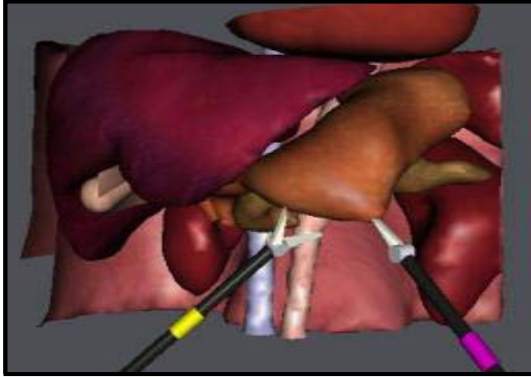


Fig. 2. Deforming the stomach.

Within any view, the instructor can remotely grasp the student's tool, to haptically guide it (and the student's hand). The student can feel the force of the instructor's guiding hand and vice versa. This is implemented by providing a distance-dependent attractive force on each machine, using the tool position from the remote machine detected at 1000hz. It needs a dead zone around the co-location point, as well as temporal smoothing to avoid vibrations.

Users can apply diathermy to tissue as well as, clip and cut ducts. The diathermy tool produces bleeding if it accidentally touches the gall bladder or any of the ducts. A touch-sensitive surface triggers this. It is possible for the duct to rupture, emit fluid and eventually break if stretched until the tension is too great. Each duct segment can trigger this through knowledge of the internal spring forces. Fluid flow representation of blood and bile is implemented with simple droplets which 'evaporate' after a given time.

The instructor is able to also annotate the scene by drawing arrows, circles and lines in 3D using the phantom's button. No haptic feedback is provided while drawing in the space around the 3D model, apart from normal surface touching. We also provided a virtual whiteboard, virtual medical scan viewer and virtual video player in the 3D scene. All these objects can be touched and drawn on in the manner of a ball-point pen, with a touch sensitive surface triggering the flow of 'ink'. This was found to assist in collaborative discussion.

We developed the application using the Reachin Core Technology API – a scene-graph API that provides both haptic and graphic rendering of the scene. We use replicated databases on each machine with update data being transferred between them when necessary over 'remote routes'. These use TCP-IP for low frequency updates and UDP-IP for high frequency updates.

3. Results

In the audience survey, the interaction between the surgeons was rated as very good to excellent by 97% of respondents and 87% rated the remote teaching as very good or excellent. Haptic interaction during organ manipulation was rated as very useful by 85%, and 89% rated the ability to be haptically guided by an expert surgeon as very useful. All respondents reported a high sense of presence with their teacher and 87% engaged highly with the scenario.

4. Future work

We plan to allow more than two collaborators and are also adapting this technology to other surgical scenarios [4].

5. Conclusion

The demonstration showed that it is possible to overcome the technical difficulties involved in presenting a haptic teaching environment, linking two institutions across the world. The resulting feedback provides encouragement for further exploration in these directions. It showed that remote demonstration and discussion need not be limited to conventional video conferencing technology. A more complete description of this trial is available in a CSIRO internal report available from the author.

6. References

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