A Simulator for Training a Full Mastoidectomy Procedure

Christopher Sewell, Dan Morris, Nikolas Blevins, Federico Barbagli, Kenneth Salisbury
Computer Science Department, Stanford University
AI Lab, Gates Building, 353 Serra Mall, Stanford, CA 94305, USA
Department of Otolaryngology, Stanford University
801 Welch Road, Stanford, CA 94305, USA
{csewell, dmorris, nblevins, barbagli, jks} @ stanford.edu
Presenter: Christopher Sewell

In this demo, we display the features of our simulation of a mastoidectomy, a surgical procedure in which a portion of the temporal bone is drilled away in order to access the inner ear. In our physical simulator, a hybrid data structure is maintained that allows computation of appropriate drill forces using rapid collision-detection in a spatially discretized volumetric voxel representation while graphically rendering a smooth triangular mesh that is modified in real-time as the voxels are drilled away. Realistic drill sounds, based on data recorded in a bone drilling laboratory, are produced, with frequencies giving cues to bone depth. Other graphical effects include bone dust and blood (both of which can be removed using a suction controlled by a second haptic device) rendered according to particle simulations, shadows, and detailed anatomical models of surrounding structures and of the inner ear.

In addition, higher-level training and evaluation are performed through the interaction of this physical simulation with an event engine and a performance evaluator. The event engine tracks the progress of the procedure, detecting such actions as collisions between the drill and critical anatomical structures or the achieving of proper exposure of such structures, which can trigger responses ranging from instructional messages to changes in the physical simulation (such as the initiation of bleeding). It uses a model of the procedure, representing the relevant events to detect and actions to take, which may depend on the current state of the simulation, which is developed by an instructing surgeon using a graphical scripting environment that makes use of finite automata.

Trainees are also evaluated on their ability to maintain proper visibility of the drilling region and their application of appropriate drill forces and velocities (as a function of distances from key structures), which have been learned from exemplary runs of the simulation by an expert surgeon. In addition to quantitative scores, constructive criticism is provided in the form of interactive visualizations that clearly illustrate regions in which proper technique was or was not demonstrated.