PAPERS

Surgical Simulation System Based on a Mass-Spring Model

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BACKGROUND

For a surgical simulation system to be truly useful, it must provide a level of realism appropriate for the task. This requires the system to not only provide sufficient visualization of the surgical environment, but also physically realistic simulation of the dynamics of the tissue involved. We have developed a system that incorporates a mass-spring model of soft tissue deformation into a virtual environment that has produced a number of applications for surgical planning and training.

PURPOSE

The purpose of this system is to provide patient-specific planning and a generally applicable training tool. The system not only allows the surgeon to visualize the data for their patient, but to extract the quantitative information required to fully understand their condition.

Further, they can practice the procedure again and again to ensure a superior surgical result. In turn, this can also lead to decreased time in the operating room and a corresponding reduction in the cost associated with these procedures. As a training and education tool, this system can result in a faster learning curve and decreased use of animals for training.

METHODS

The visualization and simulation system consists of a Sun workstation (Ultra60 Elite3Dm6), an Ascension Technologies electromagnetic tracker (miniBird), stereo glasses (StereoGraphics Corp), and a number of surgical tools which we have adapted to be computer input devices.

The visualization component of the system allows the user to view the mesh data in stereo as wireframe, solid, or semitransparent objects. The system is coupled to the surgical tools and provides for object manipulation, grasping, cutting, and other interaction.

A soft tissue object is modelled as nodes (point masses) connected by edges (springs) which are grouped in triangles for the purpose of visualization. Forces are exerted on each node by the adjacent springs, by damping, by torsion between adjacent triangles, and by the surgical instruments controlled by the user. Known physical properties of tissue are used to provide appropriate values for these forces and ensure realistic simulation. A simple and fast iterative numerical method (Euler's method) calculates each node's position and velocity based on these forces, which can then be used to deform the object in real-time. The system uses constraints to limit processing requirements to provide for increased scalability while maintaining adequate update rates.

RESULTS

This general surgical visualization and simulation system is currently used for a number of applications in microsurgery, endoscopy, craniofacial surgery and other areas. This integration of visualization and simulation allows the system to be used for modeling the dynamics of any soft tissue and providing the surgeon with the increased realism required for enhanced planning and training.

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