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Toward Realistic Soft Tissue Modeling for Virtual Surgery Simulations*

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Abstract

Realistic modeling of complex, non-rigid, and three-dimensional tissues and organs is a critical technique for computer-aided virtual surgery simulations. The reality of such simulations can be significantly improved by utilizing interactive deformable models and haptic simulations of soft tissues. In this work, we present a deformable model for real-time graphic simulations of soft organs and tissues. The proposed method, a physically-motivated model, can generate real-time realistic deformations utilizing high-resolution triangular surface meshes of CT-based organ data. The surface mesh of the object is modeled by a mass-spring system representing the connectivity of mesh nodes. Object deformations are simulated by computing nodal displacement based on a force equation at each mesh node. A deformed node index table (DNIT) is proposed to model deformation propagations driven by displacements at the surface contact point (SCP). In order to generate visually realistic deformations, model parameters, the spring constants in the mass-spring model, are tuned by matching the deformation generated by the proposed model to that generated by a ground true model. In addition, to simulate realistic haptic sensation of tissue materials, a PHANToM robotic haptic device is integrated in the simulator. Coupled with the real-time visual feedback generated by the proposed deformable model, the simulator allows a user to interactively manipulate virtual organs utilizing the PHANToM device. Results of a virtual kidney biopsy simulation are presented, illustrating the deformations of a kidney model.

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