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NEW TECHNIQUES FOR COMBINED FEM-MULTIBODY ANATOMICAL SIMULATION

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Summary: Effective simulation of human anatomical structure and function often requires combining low-fidelity models with fast computation times and high-fidelity models that emulate detailed tissue dynamics but have slower computation times. Multibody methods are typically used for the former, modeling structures such as bones, joints and point-to-point muscles, while finite element methods (FEM) are typically used for the latter, modeling deformable tissues and capturing internal stress/strain dynamics. In this presentation, we describe new techniques that are being introduced into ArtiSynth (www.artisynth.org), an open source simulation platform that permits researchers to combine multibody and FEM techniques and hence leverage the advantages of both. These include:

Reduced coordinate modeling. This is a technique in which a deformable body is modeled using a global deformation basis instead of finite elements. It spans the gap between FEM methods and rigid bodies (themselves reduced models condensed to purely rigid motions), and can be very effective in speeding up simulation times for models in which the range of typical deformations is constrained (such as tongue motions in speech production).

Skinning and embedded meshes. This entails attaching a passive mesh to a set of dynamically active bodies so that it deforms in accordance with the motion of those bodies. ArtiSynth allows meshes to be attached to collections of both rigid bodies and FEM models, facilitating the creation of structures embedded in, connecting, or enveloping a set of underlying components. For example, when modeling the vocal tract, separate components describing the tongue, jaw, palate and pharynx can be connected together with a surface skin to form an airtight mesh.

Deformable body attachments. Artisynth supports various ways to attach both rigid bodies and points directly to deformable bodies, providing different means for connecting model components together, and allowing (for example) the force of a point-to-point muscle to be distributed across a prescribed volume of deformable tissue.

Our presentation will also describe other new features, such as muscle wrapping, and review some of the basic theory by which multibody methods may be extended to the FEM domain.