Title: Inverse Anatomical Modeling and Simulation of Virtual Humans

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Abstract:

In this dissertation, we focus on a mechanical aspect of a human body and face modeling. We leverage existing physics-based models of elasticity and use them as building blocks to create an animatable virtual human. We model different types of hard and soft tissues to enable our model to contract muscles, interact with an environment or realistically deform when subjected to external forces. In the first part of the work, we present a method to create personalized anatomical models of human body ready for physics-based animation, using only a set of 3D surface scans. We start by building a template anatomical model of an average male which supports deformations due to both 1) subject-specific variations: shapes and sizes of bones, muscles, and adipose tissues and 2) skeletal poses. Next, we capture a set of 3D scans of an actor in various poses. Our key contribution is formulating and solving a large-scale optimization problem where we compute both subject-specific and pose-dependent parameters such that our resulting anatomical model explains the captured 3D scans as closely as possible. Compared to data-driven body modeling techniques that focus only on the surface, our approach has the advantage of creating physics-based models, which provide realistic 3D geometry of the bones and muscles, and naturally supports effects such as inertia, gravity, and collisions according to Newtonian dynamics. The second part of the thesis focuses on the inverse facial modeling. The human face is an anatomical system exhibiting heterogenous and anisotropic mechanical behavior. This leads to complex deformations even in a neutral facial expression due to external forces such as gravity. To obtain data on facial deformations we capture and register 3D scans of the face with different gravity directions and with various facial expressions. We show two approaches of model building either from an anatomical template or leveraging data from magnetic resonance imaging for more accurate modeling. Our main contribution consists in formulating and solving an inverse physics problem where we learn mechanical properties of the face and match expressions by novel muscle activation models while taking into account collisions. We demonstrate that our model generates predictions of facial deformations more accurately than recent related physics-based techniques.

Keywords: computer animation, physics-based simulation, anatomical modeling, numerical optimization