Chapter XII
Graphical Modeling of Human Muscles

X. Ye
Medicsight PLC, UK

F. Dong
Brunel University, UK

ABSTRACT

Muscle simulation is an important component of human modeling. However, there have been few attempts to demonstrate, in an anatomically-correct way, muscle structures and the way in which these change during motion. This chapter proposes a feature-based approach to muscle modeling which attempts to provide models for human musculature based on the real anatomical structures. These models provide a good visual description and form a sound basis for further developments towards medically-accurate simulation of human bodies. Three major problems have been addressed: geometric modeling, deformation and texture. To allow for the wide variety of muscle shapes encountered in the body, the geometric models are based on muscle features identified from radiological data. The results are realistic models with correct anatomical structures, the deformation of these muscle models is fully controlled by, and consistent with, the motion of underlying joint. We suggest a general deformation model that can be adopted for many of our muscle models, but we also model separately the deformation of specific cases for which the general model is not suitable. Interactions between muscles are also taken into account to avoid penetration occurring between adjacent muscles in our model. To provide a suitable visual effect, an algorithm was developed to generate the muscle texture directly on the model surface, rather than by using conventional pattern mapping on to the surface. Some results are presented on the geometric modeling, the deformation and the texture of muscles related to the knee.

INTRODUCTION

Human simulation is an area which has fascinated researchers in computer graphics for many years. The associated problems are very complex, involving the definition of deformable shapes, the calculation of articulated-body motion with complex joints and the overall control of the figure within a dynamic environment.

The multifarious aspects of the problem have been tackled by many researchers, including Cohen (1992), Hodgins and Pollard (1997), Gleicher (1998), Laszlo (1996), Funge et al. (1999), Maurel and Thalmann (1999), Scheepers et al. (1997) and Wilhelms and Gelder (1997). In most of the published work, the authors have adopted very simplified models. While they may have suited the authors' purposes, these simplified models cannot truly be considered to represent the functioning of an actual body.

As technology has improved, the methods adopted to tackle the complex problems involved with body modeling have become increasingly sophisticated, and the flood of publications in this area shows no sign of abating.

A recent example by Savenko et al. (1999) adapted work by Van Sint Jan et al. (1998; 1999) on knee kinematics to create an improved joint model for figure animation that is more in keeping with newly-available biomechanics data.

If the models to be created are to represent, effectively, the full complexity of the human body, then muscle simulation is one of the fundamental areas that has to be addressed.

The structure of even a single muscle is very complex. However, muscles also stretch across joints and are arranged alongside or on top of each other, so there is regular interaction with other moving or deformable parts of the anatomy. In addition, there exists a wide variety of irregular muscle forms.

Any attempt at realistic muscle simulation should address three major problems:

- **Muscle geometry:** It is difficult to find a general graphics primitive for muscle modeling because of the large number of free-form muscle shapes. Although muscles fall into several categories, such as fusi-form, uni-pennate, bi-pennate, multi-pennate, and triangular, muscles within a category may, in fact, be quite different from one another.
- **Muscle deformation:** The form of a muscle could appear shorter and thicker when contracted, and longer and thinner when stretched. In other words, the same muscle should appear differently in different actions and poses.
- **Muscle texture:** Texture is a distinctive feature of each muscle and relates to the orientation of the muscle fibers. The textures appear quite different from one muscle to another, and the model must be capable of faithfully representing these differences.

In fact, muscle structure is so complex that it is unlikely that a general muscle model will succeed. This leads to the motivation of this work.

This chapter proposes an approach to anatomy-based muscle simulation in which the geometry, the deformation and the texture of each muscle is modeled individually according to its features. The main purpose is to bring muscle models one step closer to the real anatomical structure.

The process involved three main steps addressing the three major problems identified above.

Firstly, muscle features were extracted from the Visible Human Data to build geometric models for the muscles. Because it is very difficult to create a general model to describe all types of muscle, each muscle was individually built based on its own features. Secondly, deformation models were developed to describe the deformation of the muscle models produced in the first step. These deformations are fully controlled by the muscle model attachments on the bone, the motion of which follows the extension and flexion of the joint. Interaction between muscle models,