Medicine Meets Virtual Reality
J. D. Westwood, H. M. Hoffman,
D. Stredney,and S. J. Weghorst (Eds.)
IOS Press and Ohmsha, 1998

MODELING OF A KNEE JOINT FOR THE VRDA TOOL

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Abstract. We propose in this paper a novel method for the modeling of the motion of anatomical joints. The method is based on collision detection and knowledge of biomedical experimental data.

1. INTRODUCTION

Modeling of dynamic anatomy is a milestone within a larger effort that is the design and implementation of the Virtual Reality Dynamic Anatomy Tool (VRDA) tool developed at the Center for Research and Education in Optics and Lasers (CREOL) at the University of Central Florida [1]. Medical students have typically access to still illustrations of the anatomical joint to create a mental model of their motions. This tool will allow a user to see a virtual image of the inner part of a body joint projected dynamically on top of a real joint of a subject. This paper addresses the modeling at the kinematics level of a three dimensional geometric model of a knee joint. The novelty of the method described is the use of exact collision detection to perform the automatic precomputation of the joint kinematics based on the geometry of the bone model and some constraint related to known parameters extracted from the biomedical literature. This method is naturally extensible to others joints of the human body.

2. PURPOSE

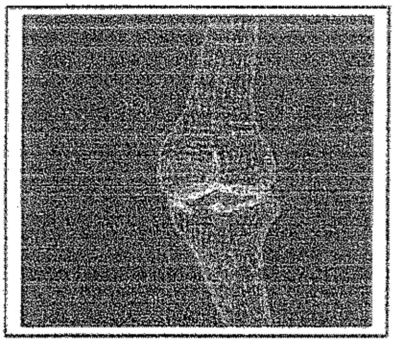
The purpose of the VRDA tool is to allow the user to manipulate the joint of a subject and simultaneously visualize a virtual dynamic model of the anatomy in order to achieve the impression of seeing inside the joint. This mode of representation is expected to help medical students form more accurate mental model of dynamic anatomy in a shorter period of time compared to current learning processes. The proposed modeling method allows fully automatic modeling of motions. Once off-line modeling is completed, look-up tables can be generated for various motion parameters so that real-time simulation can be achieved.

3. METHODS

We use a high-resolution geometric model from Viewpoint Inc. described as a set of polygons. The original model is in the extension position and includes the bones, the meniscus, the ligaments, the tendons, and the muscles. The bones will be the only parts considered in the first part of this project. They are modeled as three rigid bodies: the patella, the femur and the tibia-meniscus-fibula. In the real time simulation, the knee joint of a human subject will be tracked using accurate optical tracking, and the animation model will be driven accordingly. Thus, it is only necessary to specify the motion model of the virtual joint at the kinematics level. We consider two degrees of freedom as entry to our model: the flexion and the varus/valgus angles; the internal/external rotation of the femur is considered to be a consequence of the geometry of the contacting surfaces and therefore will be automatically accounted for.

The reaction forces and the forces produced by the ligaments (e.g. anterior cruciate, posterior cruciate and lateral ligaments) are responsible for the range of motion, the degrees of freedom and the position of the contact points [2-3]. We use exact collision detection to produce the reaction forces of the surfaces with a C library called RAPID. Motions along the remaining degrees of freedom replace the forces exerted by the tendons in order to achieve equilibrium in the final contacting position. A lookup table is then created for each flexion and varus/valgus angles. The output of this table gives the position and orientation of the tibia and the patella in this configuration for real-time rendering during simulation.

4. RESULTS



The model has been transformed in triangle primitives from the Inventor format and an application has been created to find the contacting position for any given orientation of the tibia and the patella with respect to the femur. The contact point is a constraint during the optimization process. The internal/external rotation of the tibia, which is a consequence of the geometry as well as of the entry angles is under implementation.

5. CONCLUSION

A novel method of automatic modeling based on collision detection and partial knowledge of biomedical parameters is described. The promise of this technique is that precomputation can be done off-line and a lookup table generated from the modeling can be used for real-time rendering. This modeling method can be easily implemented to generate a user-friendly tool for modeling of the motions of various joints. No such tools are currently available.

6. ACKNOWLEDGMENT

A first award from the National Institute of Health 1-R29-LM06322-01A1 supports this research.

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