CLINICIAN-FRIENDLY SOFTWARE FOR BIOMECHANICAL MODELING AND CONTROL OF MOVEMENT

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INTRODUCTION

Research in biomechanics of movement and its applications to rehabilitation and restoration of movement require sophisticated musculoskeletal modeling software (MSMS). The currently available software packages have limited functionality, their use requires high-level programming expertise, and they are expensive (Davoodi *et al.* 2003). We have formed a core software development team to lead a collective effort by the biomechanics community to develop free and open-source software for musculoskeletal modeling that will satisfy the requirements of both researchers and clinicians. The effort is directed from our laboratory at Alfred Mann Institute (AMI) for Biomedical Engineering. We are motivated to lead this effort because AMI has pioneered the development and clinical application of BIONs™ (Loeb *et al.* 2001). This technology platform of wireless, injectable stimulators and sensors can be applied to a wide range of sensorimotor disabilities, but only if clinicians have accessible and reliable software tools to fit them systematically to individual patients.

METHODS

The statement of requirements is the first step in MSMS development in which all the features of MSMS are discussed and documented before writing a single line of code. A series of meetings between the software developers and researchers from different fields have produced documents that detail the requirements for MSMS.

The *vision document* identified the main users and their key requirements, provided a high-level analysis of the key features, and justified the decision to develop MSMS as open source software to promote its adoption by the research community and ensure its continuing evolution and growth. Various usage scenarios such as "building a model" or "forward dynamic simulation" were analyzed in *use case analysis*. Each use case analysis identified the primary users (actors), the goals, and the step-by-step sequence of actions to complete the task. Finally, based on the above requirement analyses, *software architecture* was designed that includes three top-level blocks: graphic user interface (GUI), Modeling and Simulation, and Database.

Development and testing of the MSMS were started after the completion of the requirements specification. We are using a method known as *iterative development,* in which consecutive three-week iteration cycles add more functionality to the MSMS until all the requirements are met. Each iteration produces an executable code that enables us to test the developed components for functionality and integration. As a result, we can discover the integration problems early in the process, which are then easier to remedy. We are using Java as the main

programming language for development of the GUI, modeling, and database units. But computationally intensive dynamic simulation unit will use more efficient C programming language and Simulink simulation environment. We have performed a comprehensive test to select dynamic engines for dynamic simulations in MSMS. The details are described in a companion paper in this proceedings (Montazemi et al. 2004). The eXtensible Markup Language (XML) is used to define the standard model file formats.

RESULTS AND DISCUSSION

The implementation effort to date has resulted in a basic graphical user interface that could load, visualize, and animate the musculoskeletal models developed in SIMM (Fig. 1). We have implemented cylindrical wrapping objects and we are adding more to accurately model muscle wrappings around bony surfaces (Garner & Pandy 2000).

As a collective effort, the success of MSMS depends on active participation by the research community. The core development team at AMI is currently consulting with a group of thirteen prominent researchers in different musculoskeletal modeling fields in their area of expertise. They are helping to define the requirements for MSMS, define standards for musculoskeletal models, and test the alpha releases of the MSMS in their own applications. The larger community will be involved in the development through a central web page. They will provide feedback on the standards for musculoskeletal modeling drafted by the development team and consultants and test the beta releases of the MSMS.

Once developed, the MSMS will be distributed freely to the public. Procedures will be provided to enable end users to expand the MSMS with new features as new methods and data become available. We think this is essential because rapid advances in movement science and software algorithms produce new models and data that must be incorporated into pre-existing models with minimal effort. For the latest developments visit http://ami.usc.edu/msms/

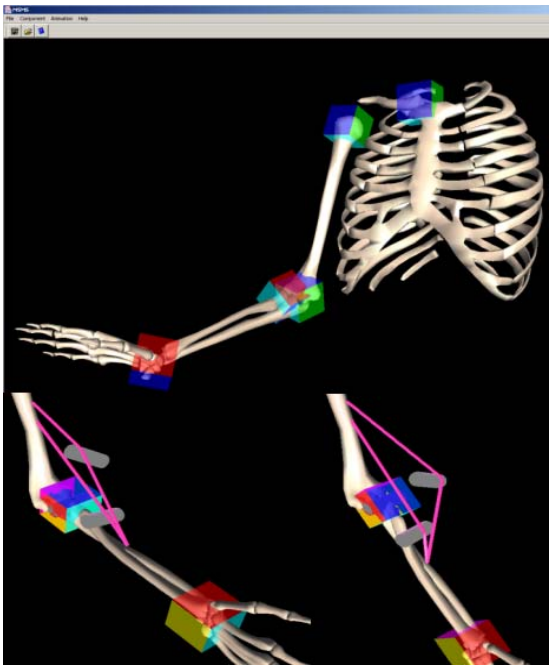

Fig. 1. The graphic user interface of MSMS under development. Muscle wrappings around cylindrical surfaces are shown.

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