

# DEVELOPMENT OF A VIRTUAL INTERFACE FOR CLINICAL MUSCULOSKELETAL BIOMECHANICS VISUALIZATION

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## INTRODUCTION

Computer-based visualization of experimental data and output from numerical models is essential for gaining insight into the structure and function of biomechanical systems. While a number of investigators have developed elegant three-dimensional models of gait and muscle actions using graphics workstations for visualization of their analyses (Kepple, 1992 or Delp and Loan, 1995, for example), the ability to create intuitively meaningful representations of the resultant motions, forces, and torques has been hampered, to some extent, by the inherent limitations of standard two-dimensional computer displays.

Applications in the burgeoning field of virtual reality (VR) have the potential to address and overcome many of the limitations in current techniques for scientific visualization. Along with support of persons with disabilities and the visual support of surgical procedures, the visualization and simulation of anatomic and biomechanical function has been identified as one of the most promising fields of application for the integration of VR and medical education and research (Kaltenborn and Rienhoff, 1993). Several enthusiastic commentators have predicted a "revolution" in medical education (Dumay, 1995) and the enhancement of overall patient care (Zajtchuk and Satava, 1997) with the use of VR in allowing students and clinicians to explore both basic science and unusual case studies. The preliminary use of VR in studies of the vestibular system (Viirre, 1996) and in the diagnosis of pathologies leading to deficits in hand function (Dumay, 1995) suggests that VR-based methods of whole-body motion analysis would be highly beneficial to the evaluation of deficits in gait and motor control.

## METHODOLOGY

The current virtual model developed in this project, shown in Figures 1 and 2, is anthropometrically correct and can move and walk relative to its stationary virtual surroundings. Anthropometric measurements for 50<sup>th</sup> percentile United States males and females (Chaffin and Andersson, 1991) were used in conjunction with custom software written in C++ and OpenGL<sup>TM</sup> in order to construct the polygonal representation of the body and simulate the relative motion of each body segment. While this model is capable of depicting programmed motion based on predetermined limb trajectories, current development has focused on the visualization of experimental data related to balance control in the elderly (Wojcik, et al., 1998). Three-dimensional kinematic data recorded with an Optotrak® motion capture system has been integrated with the anthropometric model for direct three-dimensional visualization of the balance recovery process after a forward fall.

The next stage of experimental data visualization includes color-coded depictions of the forces and torques present at each joint on the virtual representation of the test subject. A recursive Newton-Euler algorithm starting from recorded foot-floor interactions is used for the calculation of forces and torques at each joint. While the present model utilizes only a two-dimensional inverse dynamics analysis in the sagittal plane, integration of a full three-dimensional analysis is under development.

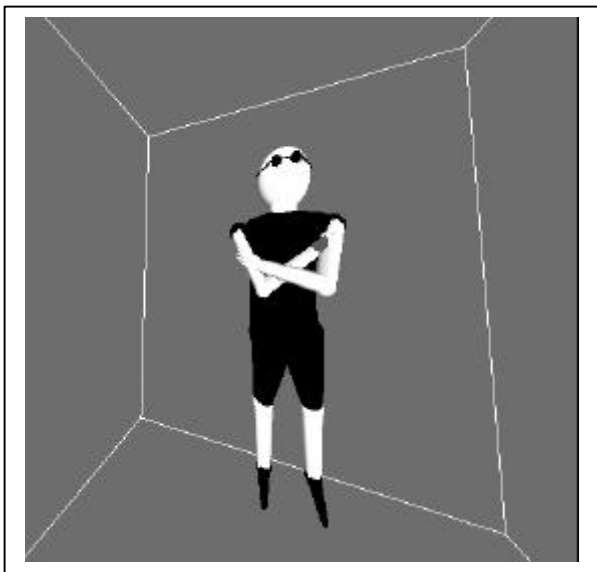
Current plans for the fully theoretical version of the model also include giving the operator the ability to "push" or otherwise perturb the balance of the model while in the

virtual environment. This real-time interaction and perturbation of physiological parameters will lead to the model's greatest benefits in terms of both educational and clinical insight.

## DISCUSSION

According to Hoffman and Vu (1997), the development of VR tools for use in surgical simulation and other medical applications will follow a five-step taxonomy, moving from simple rendering of objects in three dimensions to full incorporation of microscopic anatomy and biochemical processes. The model developed in this project helps to move the current generation of VR simulations more fully toward the second and third stages of the taxonomy, in which real-time dynamic effects and physiological characteristics are added to static three-dimensional rendering. By using this visualization tool, clinicians and academic investigators will be able to analyze and visualize biomechanical models that provide full three-dimensional simulation of human motion.

No single set of visualization techniques can possibly lend itself to all biomechanical systems. The strengths of the virtual environment do seem to indicate, however, that the potential for direct manipulation of three-dimensional models and real-time interaction makes VR extremely attractive for the visualization and exploration of physiological factors affecting human posture and motion. It is hoped that the models developed in this project will lead to increased educational and clinical insight into human motor control.



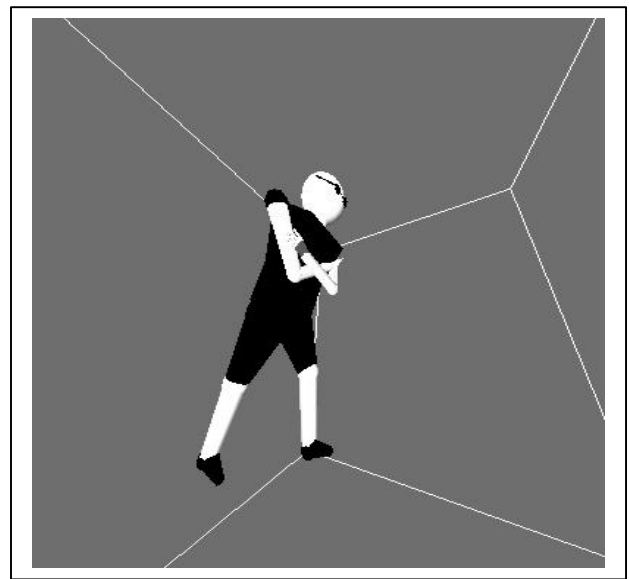
**Figure 1.** Virtual person in experimental starting position

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**Figure 2.** Virtual representation of experimental data from one young male subject's stepping response to a forward balance perturbation