The Santos® Approach to Digital Human Modeling

All research and development associated with any of SantosHuman Inc.’s products add to a foundation of virtual human modeling capabilities, housed within a digital human model which has come to be referred to as Santos® (Abdel-Malek et al, 2008; Marler et al, 2008).

Santos® is the name that has been used to reference a highly realistic, physiologically mechanistic, biomechanical computer-based digital human model that can be used to predict, among other things, static posture, dynamic motion, joint strength, and development of fatigue. Santos® Pro is one of SantosHuman Inc.’s products that contain the Santos® technologies which can be used to predict and assess human function, providing task performance measures and ergonomic analysis. Thus, in a virtual world, Santos® can be used to help design and analyze various products and processes. In addition, Santos® can help study and evaluate various restrictions and impediments, such as fatigue, reduced range of motion, environmental obstacles, etc.

Currently, Santos® technologies are being used to; help design body armor systems and to study the physiological effects of extended load carriage; solve problems like reach analysis in an automobile, indicating the optimal placement for seats and controls; predict if and how an operator of heavy machinery might grasp a newly designed joystick; and simulate and assist in the study of the completion of tasks such as crawling or running when carrying heavy loads or wearing restrictive clothing. Although functionally mature and able to serve as a virtual design and analysis aid, SantosHuman Inc.’s products continue to grow, with efforts to incorporate clothing models, link with blast and ballistic survivability models, and increase computational efficiency of dynamic motion prediction.

At the crux of any virtual human is the ability to simulate human posture and motion realistically and quickly, while considering external and internal loads/forces. With respect to motion, there are traditionally two types of dynamics problems that need to be addressed. In the first problem, called forward dynamics, the external forces and torques on the system are known and the motion of the system is desired. The problem is solved by integrating the governing equations of motion forward in time using a numerical algorithm. In the second problem, called inverse dynamics, the motion of the system is known (i.e., from motion capture), and the forces and torques causing the motions are calculated using the equations of motion. Both of these problems can be solved using traditional multi-body dynamics (MBD) software. The problem of predictive dynamics arises when one wants to simulate the human motion for any task. In this problem, both the joint torques and the motion of the joint are unknown. Therefore, the problem becomes much more difficult to solve. The University of Iowa’s Virtual Soldier Research (VSR) Program continues to make great strides in this respect, and has leveraged this novel optimization-based approach to successfully predict motion. With this approach, the joint angles (one for each degree-of-freedom) essentially provide design variables that are determined through optimization. The objective function(s) is one or more human performance measure, such as energy consumption, discomfort, and joint displacement. When equations of motion are incorporated as constraints, the result is a new approach to dynamics called Predictive Dynamics. This approach can be used to model human tasks, such as running, climbing a wall, and aiming a weapon. In addition, torques at the joints, ground reaction forces, velocities, and accelerations can be recovered and studied.
Note that a fundamental distinguishing factor in the development of Santos® technologies is a joint-based model. The design variables are joint angles, not activation levels of individual muscles. This approach is much more computationally tractable, often providing results in real-time. Furthermore, joint angles are relatively easy to validate. Finally, this approach allows for easy implementation of strength and fatigue models (Frey-Law et al., 2012; Xia and Frey-Law, 2008). Experimentally determined maximum joint-torques can be used to represent the strength limits for key joints (and thus major muscle groups). These limits can be compared to predicted joint torques as a post-processing technique, or implemented as constraints in the predicted motion (Marler et al, 2012). Thus, strength characteristics can be altered to see the effects on task performance and the effects on propensity for injury.

The digital human characters within SantosHuman Inc.‘s products are afforded considerable autonomy in reacting to infinitely many scenarios. In fact, we contend that human motion is task based, so various performance measures or combinations of measures can be associated with different types of tasks, thus modeling different types of behavior. The use of this approach allows one to study how and why humans move in a particular way given particular mission objectives and demands.

Although there are many currently available digital human modeling tools with various degrees of maturity, the current state of the art is insufficient for a truly human-centric approach to design. These available DHMs have very low fidelity with regards to appearance, function, and skeletal structure and tend to work as virtual mannequins rather than autonomous predictive humans. Consequently, they are not physics-based and provide only minimal feedback.

Relative to the current state-of-the-art, the digital human models used in all of SantosHuman Inc.’s products have superior fidelity both in terms of full-body skeletal degrees-of-freedom and in terms of appearance. Santos® capabilities also surpass currently available tools with respect to predictive capabilities. This is because in our products posture and motion are not simulated using pre-recorded data. Instead, they are simulated using validated mathematical models that can be re-run easily with changes in problem parameters. Consequently, our products can actually predict human interaction with products and processes. This allows, for example, changes in gait to be studied when there are changes made to the model such as weight, reduced ranges of motion, or strength characteristics. Such predictive capabilities afford the model considerable autonomy and stem in large part from the new optimization-based approach to human modeling.

Finally, as applications for DHMs expand substantially, so does the necessity for more complex and more accurate models. This in turn requires coupling of sometimes co-located sub-models for simulating various aspects of the human. In addition, DHMs are used in conjunction with other types of (non-human) models in order to evaluate products and processes, and this also necessitates integrated systems for seamless concurrent engineering. This level of multi-scale modeling and human systems integration requires a new inter-process communication (IPC) system specifically for DHMs. All of SantosHuman Inc.’s products are designed for expiation and integration with external models, and thus provides an extensive IPC library and API.

SantosHuman Inc. is the spin-off company that has THE EXCLUSIVE license with the University of Iowa Research Foundation to commercialize the capabilities which continue to be developed at Virtual Soldier Research (VSR) since 2003.