SANTOS A comprehensive human simulation environment. It enables a user to define anthropometric models of male or female, import CAD models of objects, vehicles, and scenes. It provides capabilities for interacting with SANTOS and contains a large set of analysis tools for ergonomics and human factors. SANTOS has physics based predictive capabilities and is fully interactive.

SANTOS

A human simulation system

Virtual Soldier Research – University of Iowa

- ❑ **Human systems integration**
  - ❑ Modeling systems, vehicle, or platform
  - ❑ Reachability analysis
  - ❑ Vision analysis
  - ❑ Fit analysis
  - ❑ Egress/ingress analysis
  - ❑ Maintainability analysis
  - ❑ Ergonomics and human factors-general tools
  - ❑ Optimize total system performance

- ❑ **Human Performance**
  - ❑ Task performance analysis
  - ❑ Load configuration analysis
  - ❑ Preparedness
  - ❑ GRUNTSIM
  - ❑ MALUM
  - ❑ Stability and balance
  - ❑ Mobility analysis
  - ❑ Explosive strength
  - ❑ Gear modeling equipment
  - ❑ Gear definition
  - ❑ Extended load carriage analysis
  - ❑ Biomechanics analysis
  - ❑ Physiology analysis
  - ❑ Extended load carriage
  - ❑ Varying environments
  - ❑ Thermal
  - ❑ Terrain
  - ❑ Time of day
  - ❑ Elevation incline
  - ❑ Biomech
  - ❑ Physiology analysis
  - ❑ Sensory data processing
  - ❑ Injury prediction
  - ❑ Big data analysis (sensors)
  - ❑ Motion prediction
  - ❑ Injury mitigation
  - ❑ Fatigue identification

- ❑ **Training and Sim**
  - ❑ Squadron representation
  - ❑ Blue/red team
  - ❑ Physics based simulation
  - ❑ Mission planning
    - ❑ Embedding NPC
    - ❑ Embedding Physic-based
  - ❑ MoCap to analysis
  - ❑ Behavior modeling
  - ❑ Physics-based motion
  - ❑ Trainee physiology analysis
  - ❑ Immersive
  - ❑ Embedded in VR/AR/MR
  - ❑ Behavior modeling*
  - ❑ Emotion modeling (Fear)*
  - ❑ Multi-agent cooperation*

- ❑ **Survivability/lethality**
  - ❑ Armor modeling
  - ❑ Survival analysis
  - ❑ Internal systems rep.
  - ❑ Penetration
  - ❑ Mobility/restriction

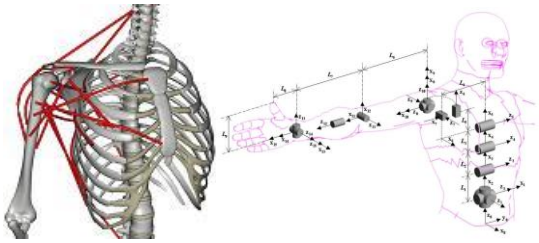
Santos Capabilities

Santos Physics-Based

Santos Task Based

Biomechanical Model

- 215 Degrees of freedom
- Anatomically correct bone models for the complete body
- Muscular system (including muscle line of action, muscle wrapping, and sliding)
- Variable anthropometry
- Male and female
- Variable strength (static and dynamic)
- High quality of realism
- High fidelity modeling
- Developed using state of the art tools (gaming engines, shaders, and physics engines)
- Predictive dynamics (using 55 DOF model, allows for prediction of forces and torques for a given task)
- Accurate 25 degree of freedom hand model including grasping



Realistic Graphical Environment

- The Santos™ environment is built on a powerful state of the art render engine that provides high-quality, real-time rendering of 3D CAD, 3D images and animations in real time. It contains the following:
- Realistic human appearance
- Realistic deformation of skin
- Real-time dynamic lighting

Allows for the positioning of various lights and motion of these lights

- Real-time shading

Allows for photorealistic shading, rendering

- Ability for texture mapping (and 3d textures)
- Ability to simulate particle systems (point clouds and
- Ability to simulate large numbers of polygons
- Support for key industry standards: DirectX and OpenGL.
- Supports programmable Vertex and Pixel Shaders.
- Optional access to render engine source code.

Allows for decals, logos, and pictures to be pasted onto moving objects
Can visualize smoke, fluids, and environmental effects)
Can import many objects into the simulation at one time (methods for polygon optimization, texture compression are enabled)
Seamless skin, including color, texture, and deformation
Realistic anatomical features, draws upon gaming technology

- OpenGL and Direct X support
- See additional data sheet for **Real-time simulation** engine and rendering capability

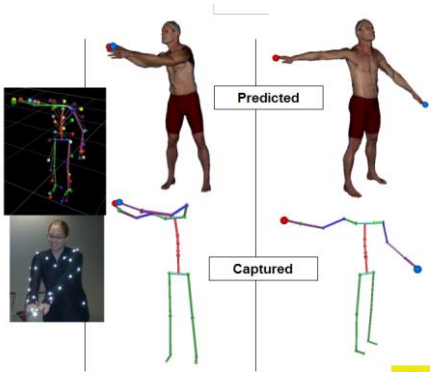
Advanced Posture Prediction

- Optimization-based using newly developed approach that yields natural postures.
- Joint limits are considered and are user changeable.
- User can restrict joint motion (e.g., disability evaluation)
- Postures are predicted using the concept of maximizing or minimizing a cost function, which is a human performance measure.
- Human performance measures include discomfort, effort, energy, vision acuity, vision displacement, fatigue, etc.
- User definable targets for limbs (upper and lower).
- Posture prediction calculated for waist to limb, or for whole body.
- Naturalistic motion and behavior obtained by combining cost functions (multi-objective optimization).
- User definable targets (point-to-point, or point and orientation, or point and grasp).
- User-definable end-effector path prediction (minimizing third derivative of acceleration).
- Responds autonomously to infinitely many scenarios.
- Study of restrictions due to outer garments are enabled (see clothing section).

Vision

- Vision-dependent posture prediction (allows for more realistic behavior)
- Vision acuity and visual displacement functions allow postures (particularly head and neck) to be calculated with great realism.

- Vision cone to allow vision analysis
- Eye cameras enabled to see what Santos sees.



Dual Arm Coordination

- Dual targets can be defined for the upper body.
- Point-to-point motion
- Point and orientation definition.
- Limbs or limbs and torso

Lower Limb Posture prediction

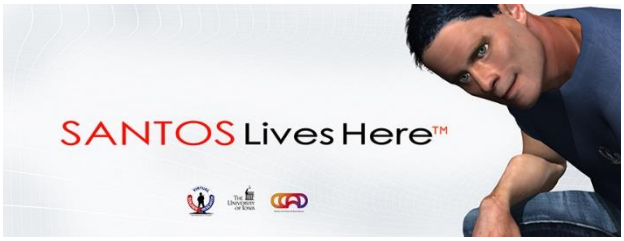
- Point and orientation definition.
- Ranges of motion are user defined.
- Performance measures are used to predict postures.

Collision avoidance (picture)

Collision Avoidance

- Postures in an environment with obstacles is enabled.
- Allows the filling of spheres into the body and environment objects
- Uses the concept of minimizing sphere distances to avoid penetration

CAD Format Compatibility



Compatible with most CAD formats
Native vrml importer
Direct export from 3DMax, Maya, Lightwave, and SoftImage.
Import for JT format (indirect)
Import for XML format (direct)

Optimized formats for real-time
Texture compression
Ability to assign mass and moment of inertia

Accepts all PLM based solutions from UGS
Accepts all PLM based solutions from Dassault Systemes

Advanced IK

- Real-time optimization-based prediction of postures.
- Ability to drag segment (e.g., hand) in real-time while predicting postures
- Ability to fix segments and drag remaining chain
- Ability to position body in a fast and effective manner.

This the most advanced method known to work for inverse kinematics for large DoFs in real-time and provides the most natural postures.

Get picture from Tim (picture)

Image and Sound Support

- Images: JPG, PNG, TIFF, TGA, BMP, PCX.
- Sounds: MP3, WMA, WAV, MIDI.
- Video: AVI, Active Movie supported formats.

Interface with Santos

- Real-time interactivity
- Graphical tools for navigating, creating, editing, selecting and manipulating
- 3D objects, lights, cameras and curves.
- Creating and editing lights, cameras, materials, textures, grids and paths.
- Intuitive interface (3rd Z-depth is intuitive)
- Translation, rotation, scaling of 3D entities and navigation within the virtual environment.
- Allows for direct manipulation of joints, ranges of motion, etc.
- Displace contents in real-time
- Drag-and-drop behaviors onto 2D and 3D objects.
- Creation of new reusable behaviors by graphically combining existing ones.

Scripting

- Scripting (visual Basic) for the advanced user
- A Script Debugger to fine-tune the application.
- Entity Setup Tools to edit the parameters of any object that has associated behaviors.
- An Attribute Manager for quick visualization and modification of attribute values for multiple objects.

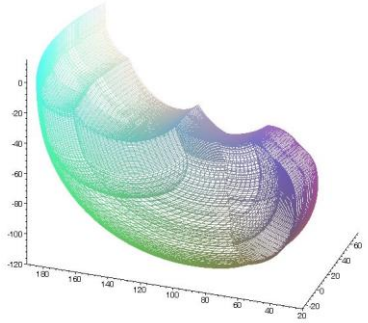
- An Action Manager to create scripts for frequently used functions which performs a predefined task on a selection or parameter and access them in just a few keystrokes.
- A Hierarchy Manager to display a tree view of all the objects present in any level.
- A Parameters Debugger to inspect and edit data values.
- A Path Manager to define paths to data sources (image, audio or other data files).
- A Profiler to probe how much computing time is devoted to particular tasks.
- A Shader Editor to create programmable vertex and pixel Shaders in DX9 (HLSL).

Anthropometric Variability

- Male and female
- Allows for scaling Santos using ANSI standards
- Allows for changing the anthropometry manually (individual parameters)
- Allows for changing body types (e.g., chest circumference).

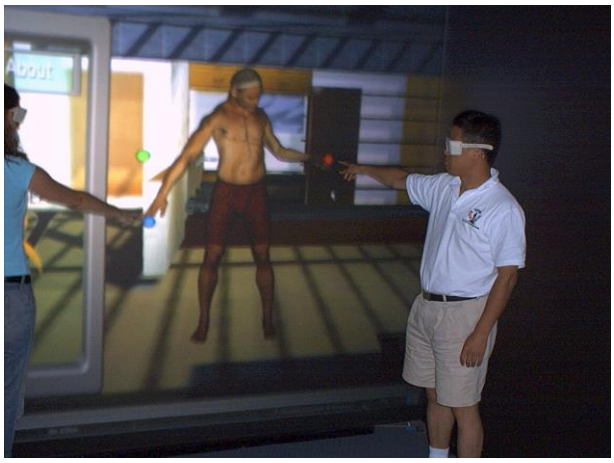
Reach envelope

- Mathematically calculates reach envelope for a limb or any kinematic chain (a series of connected segments of the body).
- Displays 3D surfaces for envelope
- Provides human performance data within the envelope (for example, evaluation of discomfort at discrete points in the envelope).
- Zone differentiation: ability to highlight in different colors zones of similar human performance measures (i.e., quantifying the envelopes).
- New methods used in visualization of the reach envelopes using volumetric cutting-plane methods.



Virtual Reality

Stereoscopic VR projection enabled
Compatible with multi-wall immersive displays
Inherently stable haptic devices
VRPN compatibility VR devices (see list in right column)
Sophisticated spatial sound synthesizer
3D input devices
Haptic devices (drivers available for many commercial devices-see list)



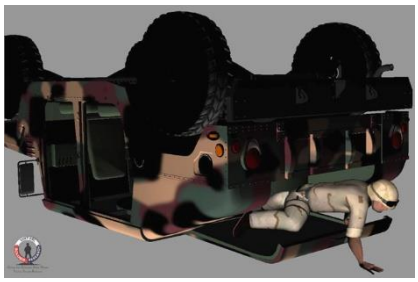
Motion Capture
Post-processing playback of Santos captured motion
Real-time Santos motion (Vicon)

- Zaber.com's linear positioning elements.

Rendering Power

The render engine provides high-quality, real-time rendering of 3D images and animations in real time. It includes the following features:

- Support for key industry standards: DirectX and OpenGL.
- Supports programmable Vertex and Pixel Shaders
- Support for 3D modeling objects and animation from 3ds max,
- Maya and Lightwave.
- Optional access to render engine source code.



Predictive Dynamics

- Ability to predict physics-based dynamic motion (predicts motion given initial and final conditions including external loads)
- Ability to calculate joint profiles (prediction of joint angles versus time)
- Ability to calculate torque profiles (prediction of joint torques as a function of time)
- Joint force and torque analysis
- External load analysis
- Balance
- Optimization-based dynamic analysis enabling increased DOF with no equations of motion
- Approach to motion that doesn't require solving
- Equations of motion are enforced\

Strength

- Hundreds of subjects have been measures through a BioDex machine for torque measurements of major joints.
- Static strength (3D SSTP) enabled.
- 3D Static/dynamic torque-velocity curves are implemented and limits are enforced.
- Varying strength for human models
-

Muscle Modeling

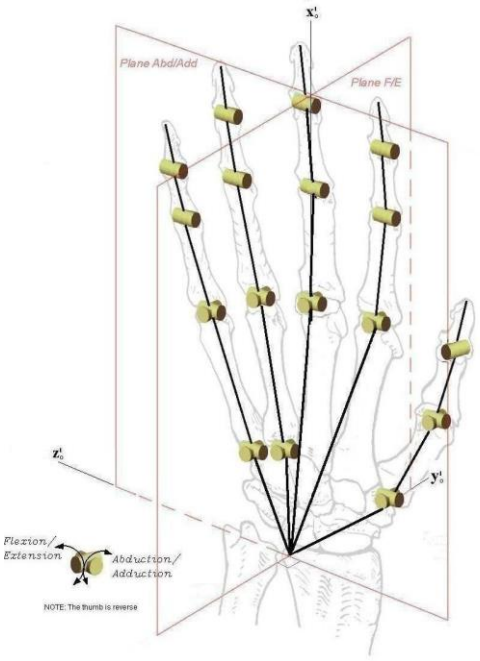
Some from Alex
Some from Laura

Fatigue

- Musculoskeletal model representation for all limbs (muscle lines of action and accurately represented)
- Real-time interactive manipulation of joints with muscle action lines
- Accurate muscle wrapping
- Accurate muscle sliding
- Predictive muscle activation through optimization
- Monitoring of muscle activation in real-time and per muscle.
- Graphical feedback of muscle moment arms

Hand Model

•1) Accurate Biomechanical Model
• 4) Forward Kinematics
•16) Graphical Interface
•3) Photorealism (and Skin deformation)
•5) Manipulation (individual joints, or coupled joints)
•6) Grasping (16 power and precision grasps)
•7) Grasp Morphing (changing of grasping from one to another)
•8) Grasp Artificial Intelligence
•9) Grasp wrapping
•10) Grasp Quality Index
• 11) Finger Pressure
•12) Joint Torque Analysis
•13) Local Biomechanics wrist and hand modeling
•14) Compliant Pressure Mapping
•15) Reach Envelopes of each Finger
•16) Evaluation of Carpal Tunnel Pressure
•17) Dexterity Analysis



- Full 25 degrees of freedom for each hand
- Coupling between joints (natural response and for easy manipulation)
- Full control over each joint (in independent mode as well as in coupled mode)
- Collision detection enabled grasping (wrap around an object)

Grasping

- Pre-stored gestures
- 16 power grasps
- 16 precision grasps

- Intelligent grasping (allows the hand to grasp a given object, autonomously)
- Grasp Quality index (based on a well-established Minimum-Disturbance-Wrench Measure of Quality)

Thermal Evaluation

Walking and Stability

- Walking prediction (joint and torque profiles)
- ZMP-based analysis
- Running prediction (joint and torque profiles)
- Weight affects gait
- RoM affects gait

Survivability (and Personal Protective Equipment – PPE)

- Armor design module
- Specifying of mechanical properties
- Effect of armor on biomechanics
- Effect of armor on mobility
- Coverage and surface areas
- Penetration and metrics for survivability

Standard Ergonomic Assessments

- RULA
- Vision analysis
- Static strength (3D SSPP 5.0.5)
- NIOSH 81/91.

- NASA 3000
- OWAS
- SNOOK&CIRIELLO
- Burandt-Schultetus
- Trunk analysis

Time analysis.

-

Clothing Simulation

Computational cloth models (based on rigorous computational mechanics)
Calculates additional torque requirements due to clothing
Calculates additional energy expenditures due to clothing
Calculates new joint ranges of motion due to clothing
Computational draping methods (digital human must wear clothing)
Cloth bulking motion restriction

Physiology

- Monitoring of vital signs
- Oxygen uptake
- Heart beat
- Temperature

SimBioSys:

- A complete patient physiology program