The Development of a Functional Visualization System for the Creation of Digital Human Models

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Abstract

This project is developing a dynamic Functional Visualization System (FVS) for the creation of Digital Human Models (DHM) of people with disabilities for use by designers and clinicians. The System employs a 'synthetic' or 'human figure model' approach and includes standard measurement procedures for the capture of anthropometric data, the development of computer programs and processes for the visualization of the data which has been captured, the verification of collected data and the investigation of the utilization of visualization tools by designers and clinicians.

Motivation

Inadequately or poorly designed environments and tools of daily living impose barriers to people with a disability. This issue needs to be addressed in order for people with disabilities to lead full and purposeful lives. To accomplish this goal it is imperative that designers of environments and artifacts have an in-depth knowledge of human functioning in the performance of tasks and problem-solving strategies to develop environments and products that best accommodate performance of these tasks. They require an understanding and useful characterizations of the abilities of people with disabilities and relevant mechanisms to incorporate this into a modern design process.

The last few years have seen an dramatic increase in Digital Human Modeling (DHM) capabilities. This technology can provide designers and clinicians the human factors tools needed in the design process. It holds the promise of allowing qualitative pre-visualization and quantitative analysis, as well as dynamic simulation, of the ergonomic relationships between humans and the products they utilize and environments they inhabit - before the products are manufactured or the environments constructed.

The effort to improve and utilize DHM technology for design purposes is important to designers and people with disabilities for two key reasons:

1) The design process is, by nature, time-intensive, non-linear and iterative which means that any pressure, such as lack of necessary information, time schedule or financial exigency will short circuit the process and lead to an incomplete or poorly designed product.

The nature and extent of inadequately designed resources has been well documented, most notable by Donald Norman [1]. This reality is experienced daily by every living person. The serious lack of designer-oriented computer-based anthropometric data for use in three-dimensional computer graphics software, has perpetuated the creation of inferior products and environments. DHM software offers significant promise to designers of artifacts and environments for human use.

2) Currently available DHM software is unsuitable for the typical design process as practiced by industrial and product designers, as demonstrated by the following facts:

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- The price point of the more sophisticated DHM applications is beyond that designers are willing or able to spend on an 'unknown' capability. As noted by John Roebuck, a respected anthropometry consultant, that while there are several highly competent computer modeling systems available, “These require high-end computers and are quite expensive”. Of the few simple/inexpensive DHM programs available, a number of unresolved issues are identified such as “the need for non-standard postures and a variety of body shapes and sizes.” [2]

- Current DHM software is oriented towards engineering applications. As has been detailed by one of the most active and visible researchers in the field of DHM, Don B. Chaffin, most users are in the fields of automotive engineering, aerospace engineering, or industrial engineering as shown in the results of a SAE G-13 Human Modeling Technology and Standards Committee survey.[3]

- Many designers have not been trained adequately to effectively and accurately use DHM. [4]

- The prevalent approach to the creation of DHMs, the so-called ‘static’ or ‘task-oriented’ approach, attempts to predict human motion using statistical models, of non-context specific tasks, from data which have been gathered in surveys. A significant aspect of this lack of context sensitivity to the problem under consideration have been described by two current researchers in the field of digital human modeling:

“... figure models can be applied to novel situations for which task-oriented models are not available; *that is, most tasks*...” [5] {emphasis mine}

“In general, models that are solely statistical in nature have bounded predictive power, *especially when extrapolated to novel, untested situations.*” [6] {emphasis mine}

Approach

This project employs a holistic approach to the generation of solutions for typical problems confronted by people with disabilities. This project is, by its very nature, multi-disciplinary and broad in scope. It will provide services and information to many groups in order to demonstrate an integrated approach to disabilities studies and provide proof of concept demonstrations that products and environments, which meet the needs of people with disabilities, can move out the realm of ‘orphan technology’ - that is, not commercially viable of its own account.

Stakeholders involved in this effort include the following: Occupational Therapist/Clinicians, Computer Programmers, Visual Communication Designers, Industrial Designers, Statistician, Participants/End User/ Specifier (in this project people with disabilities) of products created using the visualization software.

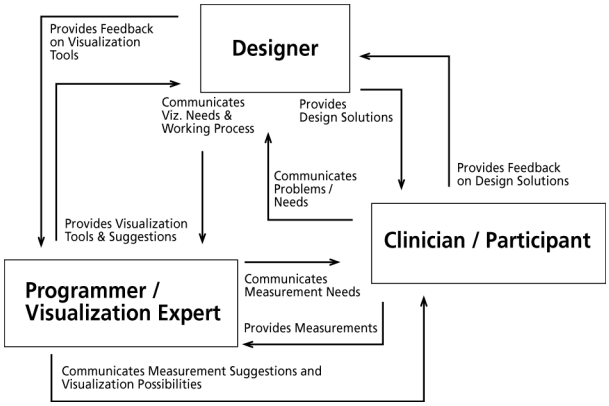

Figure 1. Some functions /relationships of the holistic design process

Validating the Process

Preliminary work done by these researchers has demonstrated the ability to create useful DHM visualizations of individuals with disabilities, based upon simple measurements of limb segment length and maximum joint angles.[7, 8, 9]

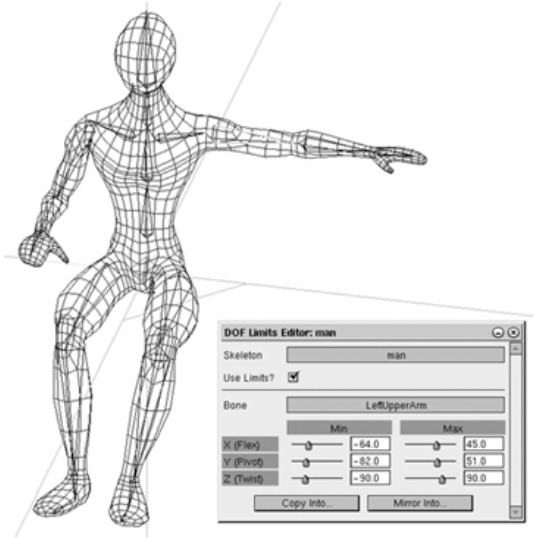

Figure 2. DOF Limits Editor window in MIRAI ®

The COTS software used in the research MIRAI includes a default skeleton with 15 segments and 12 joints. It will also create figures with any number of segments and joints. The model bone segments can be scaled to any desired length and the range of motion specified for any joint to generate motions like flexion, extension, abduction, adduction, internal and external rotation. [10]

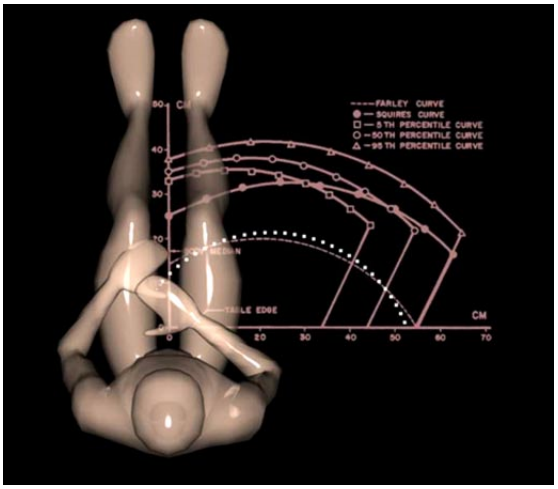

Figure 2. White dots show a close match with Farley's curve which visualizes movement with a fixed elbow.

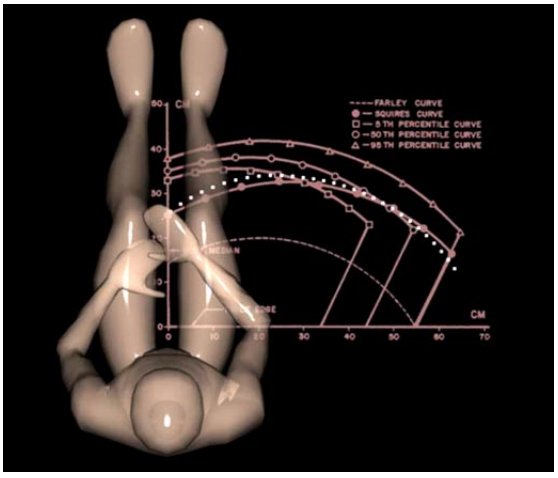

Figure 3. White dots show a close match with Squires' curve which visualizes movement that allows movement of the elbow.

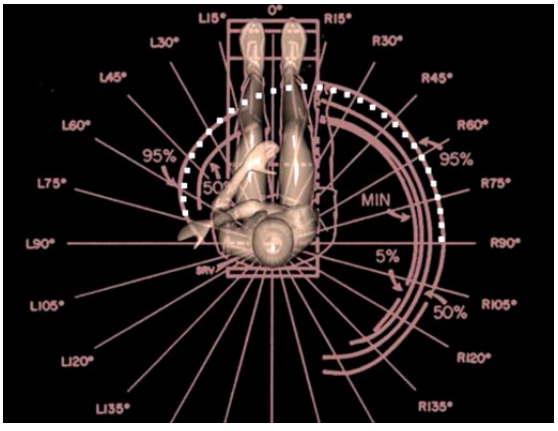

Figure 4. White dots show a close match with Kennedy's work showing arm reach, here in the HP 10 inches above SPR with shoulder fixed during the motion .

The validity of our approach has been confirmed by good comparison with measurements taken by respected authors in the field of anthropometrics, including Kennedy, Farley and Squires[11, 12]. See figures 2,3, 4.

Data Which Makes Data

Using Commercial Off The Shelf (COTS) software the researchers have extended the software's basic capabilities to create 'data which makes data'. Rather that replaying choreographed animations, or repetitively positioning a static mannequin, designers can measure and manipulate three-dimensional objects which represent Range of Motion (ROM) volumes for specific individuals or 'percentile' ranges.

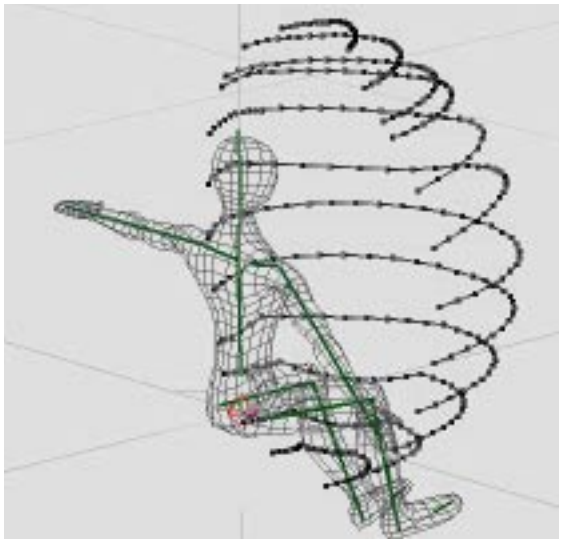

Figure 5. Maximum arm reach is developed for horizontal levels in a manner similar to the one used by Kennedy. The path data which is created can measured and transformed the same as any other 3D data.

With these capabilities a designer or clinician can create three dimensional forms which quantitatively describe *any* motion or task, be it an everyday activity or a new unique motion associated with an envisioned product or space. See figures 6,7,8.

Creating such useful models helps to overcome the specific shortcomings of traditional anthropometric visualization which cannot:

- address the dynamic nature of functional abilities
- accommodate widely varying movement capabilities and different levels of total body engagement
- dynamically incorporate anthropometric factors into the design process

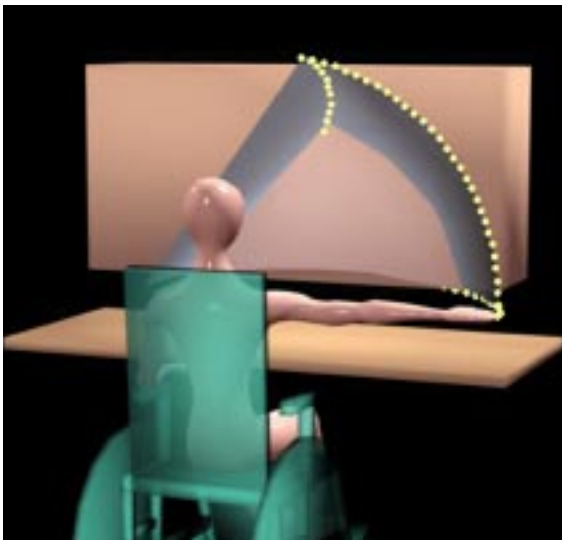

Figure 6. Intersection of maximum arm reach and cabinetry.

Current Activities

Current activities of this project include:

- the refinement of validation techniques to include the use of magnetic tracking devices
- research into the degree of quantitative precision required during various stages of the design process
- development of various procedural techniques to automatically generate a set of standard ROM envelopes
- refinement of human motion choreographic techniques for designers
- development of various procedural shape/volume querying routines

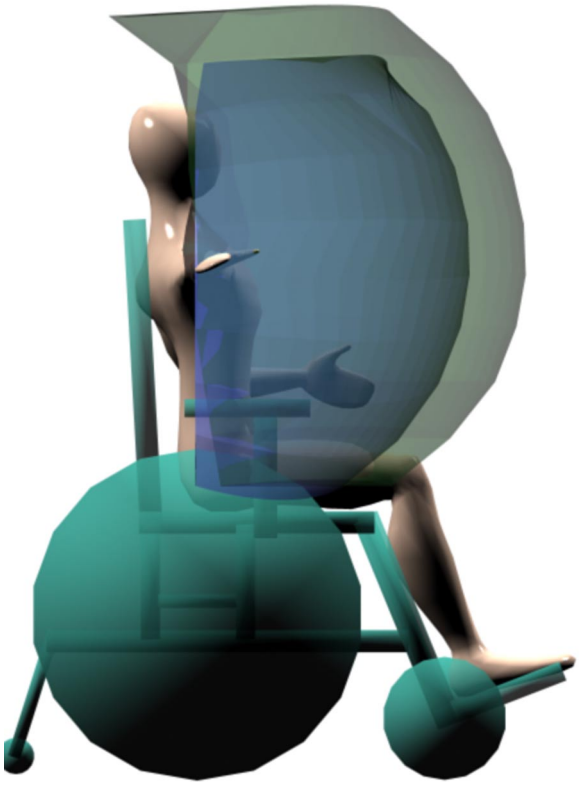

Figure 7. Side view of a comparison of a 41yr. old female with arthritis (smaller dark volume) and 95th percentile female ROM data , from Damon. [13]

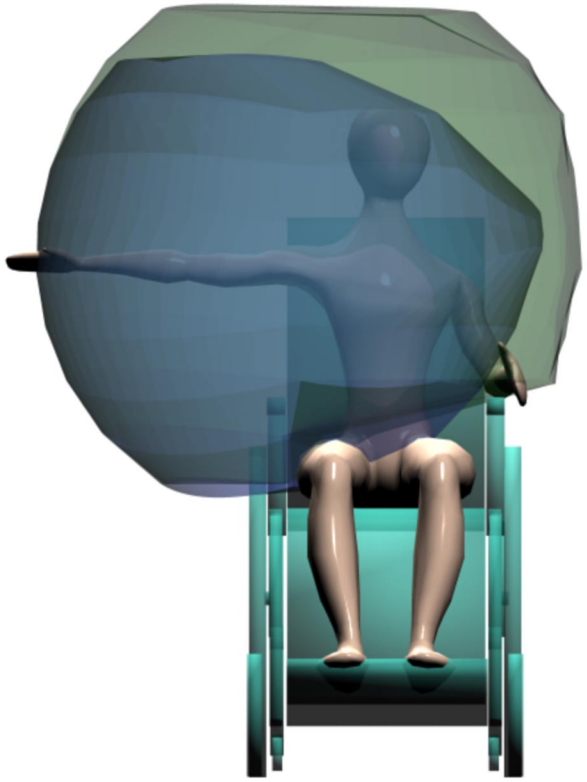

Figure 8. Front view of a comparison of a 41yr. old female with arthritis (smaller dark volume) and 95th percentile female ROM data , from Damon.

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