The Anthropometric Measurement and Modeling Project 2002

John Jay Miller
Mississippi State University

Weidong Wang
Craig Bennette Associates

Gavin R. Jenkins
T.K. Martin Center for Technology and Disability
Mississippi State University

Abstract

This paper describes a project that has been on-going since 2000 and consists of the following activities:

- specification of Digital Human Models (DHM) for the visualization of people seated in wheelchairs,
- extension of commercial off the shelf (COTS) software to enable the development of dynamic visualizations of 'data that makes data' , and
- subsequent construction of digital visualizations that are useful to designers in the creation of artifacts and environments for human use.

We have developed a process of 'data that makes data' which allows the visualization of any potential or hypothetical physical interface between a human and an environment or artifact.

Preliminary validation is provided by comparison with findings of other researchers. This work clearly suggests a need for design-oriented software that contains robust 'dynamic' digital human models capable of creating visualization for any arbitrary context.

1 Background

1.1 Motivation

Disability is now recognized as a product of the interactions between individuals and the environment they inhabit and the products they use. It is a common condition, with approximately 43 million people within the USA enduring disabling situations that interfere with their life activities (McNeil, 1993).

This project began as an effort to digitally model individuals with disabilities in ways that are useful to designers. These models are needed in order to help designers understand the abilities and constraints of the human body and to help visualize the body's possible interactions with environments and artifacts.

Historically, designers have been forced to rely on two-dimensional representations of human movement possibilities, such as those presented in the classic book *The Measure of Man* (Dreyfuss 1967). The informational limitations of attempting to represent a dynamic three-dimensional process in a static two-dimensional space is obvious, but perhaps more importantly, the nature of the human kinematic system was not fully appreciated, which led to a considerable amount of measurement error in some of the illustrations. See "The Anthropomorphic Measurement and Modeling Project" (Miller et.al 2000) for a comparison between motion represented with our DHM and the work of Dreyfuss.

People with disabilities represent a special case when attempting to model human motion because of the difficulties in measurement and subsequent verification of modeling results. Our approach reduces the impact of these issues by reducing the amount of measurement data needed to two types: limb segment lengths and joint angle capabilities. The measurements are taken with standard instruments: tape measure and goniometer. For a fuller discussion of anthropometry and ergonomics, see “Bodyspace” by Pheasant (1986).

These measurements are transferred to the DHM through the use of inverse kinematics (IK). The DHMs are then used to determine a person’s motion capabilities through the creation of computer-based task-specific motion envelopes or more general-purpose maximum range envelopes (MRE).

1.2 Precedence

DHMs have been in existence for a number of years, most notably with the work of Badler (Badler, 1978, 1979, 1988). However, only recently have computer processing speeds and memory capabilities enabled the creation of the complex models needed by designers for visualization purposes. DHMs offer the possibility of interactive qualitative pre-visualization and quantitative analysis, as well as dynamic simulation of the ergonomic relationships between humans and the products they use.

This performance issue is important because the design process is time-intensive, non-linear and iterative. Any pressure, such as a lack of necessary anthropometric information, will short circuit the process and lead to incomplete or poorly designed artifacts.

Another important issue is the approach used to make the DHM. Most of currently available DHMs are engineering-oriented (Chaffin, 2001) and are based on what is called a *task-based* or *static* approach. Though the name might lead one to think otherwise, this approach attempts to predict the outcome variable directly, using statistical data from non-context specific tasks that have been gathered in surveys. The deficiency in the approach is the lack of context sensitivity. As noted by Zhang,“ In general, models that are solely statistical in nature have bounded predictive power, especially when extrapolated to novel, untested situations.” (Zhang, 2001) This means that the reliability of these models is called into question whenever they are extrapolated for use in a task situation or context that was not included in the survey data – which would include the vast majority of situations confronting designers.

The approach we follow is called the *synthetic* or *human figure model* approach. This approach has been described as follows by Matthew Reed, an active researcher in the field of DHM: “ figure models can be applied to novel situations for which task-oriented models are not available; *that is most tasks*. For example, no task-oriented reach models for people in wheelchairs are currently available. In fact, even the reach models for people who do not use wheelchairs are not well developed. The lack of task-oriented models for many tasks make figure models essential for ergonomic analysis.” (Reed 2001) {emphasis mine}

1.3 Measurement Technique and Validation

This research uses the limb segment length and joint degrees-of-freedom (DOF), for those body segments under consideration (currently the upper body of wheelchair users). Using a COTS 3D computer graphics application, MIRAI ®, these data are used to calibrate base DHMs which represent a specific individual, perhaps with some known characteristics of a larger population, ninety-fifth percentile height data for example, as in Figure 1.

We have achieved good preliminary validation results (Miller 2001) in comparison with data developed by previous researchers, such as Kennedy and Damon. (Kennedy 1964; Damon 1966)

2 Results

2.1 Data That Makes Data

We by extended the software capabilities to create a context in which designers may view human movement capabilities as animations of limb motion or, as snapshots of full body extensions. Through this we developed a technique, "*data that makes data*", that permits the dynamic visualization of *any* motion appropriate for a given environment or artifact.

The process is as follows:

- Measurements are taken from an individual or data-base of percentiles.
- Motion choreography is created for a specified task or movement.
- Motion path data are created from any specified point on the body, such as a finger-tip.
- A series of paths are joined to create a 3D surface which delineates the task space.

The result is a three-dimensional object that can be viewed, translated, measured, etc. Various motion representations can be compared or used as the basis of traditional boolean operations. Capabilities of specific individuals can be compared with known percentile data, as shown in figure 1.

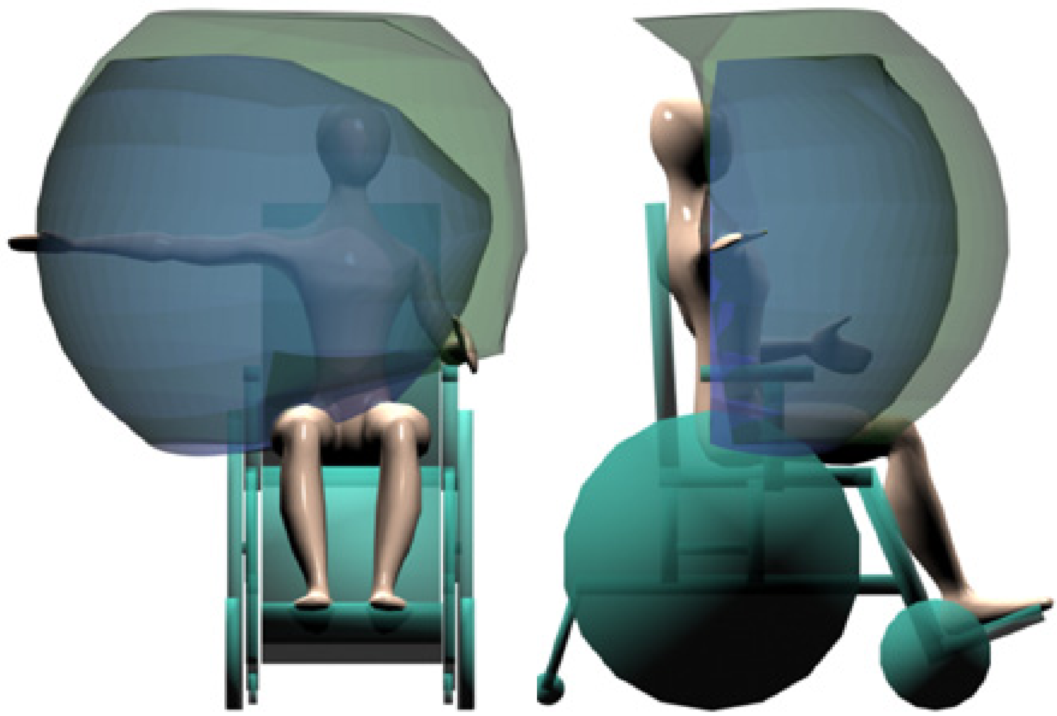

Figure 1. Front and side views of a 41 yr. old female with arthritis (smaller, darker, blue surface) and 95^{th} percentile DOF data.

2.2 The Need for Immersive Data

The development of three-dimensional objects that are based on the movement capabilities of specific individuals allows for a prolonged immersion with a representation of physical capabilities. This is opposed to the reliance on disjointed and drastically incomplete fragments of data as represented by tables of numerical data, static two-dimensional illustrations of motion, or animations of motion that must be re-played.

3 Conclusion

This project has demonstrated the use of digital human models that are based on the *human figure model* approach and developed with a minimum of invasive measurements (Miller 2002).

There is a commercial opportunity for 'plug-in' technology that will fill the need for third-party software capable of extending the various 3D modeling software currently used by designers and architects. This software should provide

• robust forward and inverse kinematic controls,
• extensive choreographic capabilities,
• a suite of procedural operations for the automatic generation of paths and surfaces, and
• a well documented API for end-user extension of the plug-in.

The educational community should reinforce the goals of user-centered and universal design through the use of such software and through project requirements which emphasize the creation of spaces and products that meet the needs of as much of the population as possible, as well as special attention to the needs of vulnerable populations.

4 Future Work

Future work scheduled for this project includes:

• further validation procedures for the 3D data already developed, using magnetic and optical motion tracking for comparison with virtual motion created in MIRAI
• implementation of a 'holistic' design process, as illustrated in figure 2, which includes the contributions and viewpoints of all relevant participants, including programmers, designers, clinicians, people with disabilities, and visualization experts
• development of visualizations that represent strength capabilities

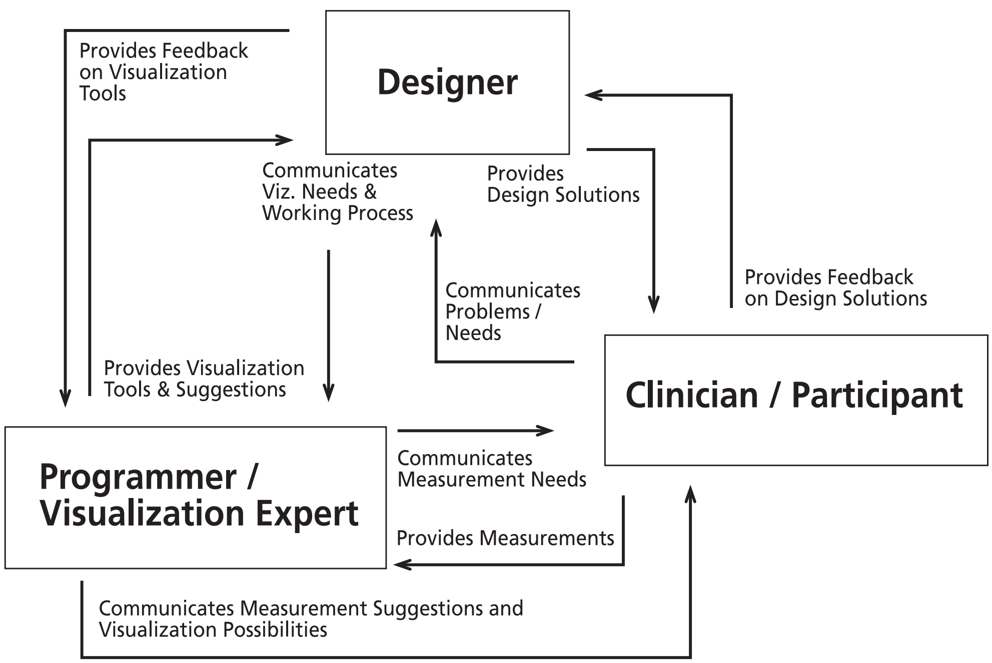

Figure 2. Some aspects of the holistic design process relationships

References

Badler, N.I., S.W. Smoliar, and L. Weber (1978). An Architecture for the Simulation of Human Movement. *Proceedings of the 1978 Annual Conference*, vol 2, ACM

Badler, N.I and S. Smoliar (1979). Digital Representations of Human Movement, *Computing Surveys*, vol 11. no 1, ACM

Badler, N.I and C. B. Phillips (1988). Jack: A Toolkit for Manipulating Articulated Figures, *Proceedings of the ACM SIGGRAPH Symposium on User Interface Software*, Jan 1988, ACM

Chaffin, Don B. (2001) *Digital Human Modeling for Vehicle and Workplace Design*. Society of Automotive Engineers, Warrendale PA

Damon, Albert, et al. (1966) *The Human Body in Equipment Design*. Harvard Press.

Dretfuss, Henry (1967) *The Measure of Man: Human Factors in Design*, New York: Whitney Library of Design.

Farley, R. R. (1955) Some Principles of Methods and Motion Study As Used in Development Work. *General Motors Engineering Journal*, 2(6).

Kennedy, K. W. (1964) *Reach Capability of the USAF Population*. Phase I. The Outer Boundaries of Grasping-Reach Envelopes for the Shirt-Sleeved, Seated Operator. AMRL-TDR-64-59 Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio

McNeil, J.M. (1993) Americans with Disabilities: *1991 - 1992 Current Population Reports*, Household Economic Studies. P70-33. Washington D.C.: US Bureau of the Census.

Miller, J., W. Wang, G. Jenkins (2000) The Anthropometric Measurement and Modeling Project, Eternity, *Proceedings of ACADIA 2000: Infinity and Virtuality in Architecture,* Washington DC, 2000

Miller, J., W. Wang (2001) Application of Computer Visualization Techniques for the Use of Anthropometric Data in the Design Process, *International Conference on Affective Human Factors Design*, Singapore, June 2001

Miller, J., W. Wang, G. Jenkins (2002) The Development of a Functional Visualization System for the Creation of Digital Human Models, (In-Press) *IEEE Proceedings of 6th International Conference on Information Visualisation*, London July 2002

Pheasant, Stephan (1986) Bodyspace: *Anthropometry, Ergomonics and the Design of Work*, Taylor and Francis, London

Reed, Matthew P., Creating Design Tools from Functional Anthropometric Data. *Anthropometrics of Disability Proceedings*, Buffalo June 2001

Zhang, Xudong. (2001) Biomechanical Realism Versus Algorithmic Efficiency: A trade-off in Human Motion Simulation Modeling. *SAE DHM Conference*, Arlington VA