Application of Computer Visualization Techniques for the Use of Anthropometric Data in the Design Process

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Abstract
The Anthropometric Measurement Project (AMP) at the School of Architecture, Mississippi State University, seeks to provide Computer Aided Design (CAD) based tools and procedures for using anthropometric data in the design process. Range of Motion (ROM) and strength information from able-bodied individuals, as well as people with disabilities, is used to create visualizations of human capabilities. The visualizations consist of queryable three-dimensional data sets. Information such as distance, volume and shape can be identified through visual and procedural measurement of the three dimensional data sets created.

Keywords Anthropometrics, Design Process, Visualization, Computer Aided Design

1. Introduction
The use of anthropometric data in industrial design was pioneered by Henry Dreyfuss during the 1940s and 50s (Flinchum, 2000). Current computer based tools can help to improve the accuracy and efficiency of anthropometric data used in the design process by utilizing well known and commercially available three-dimensional kinematic and inverse kinematic (IK) techniques to perform real-time or near real time animations of human movement which in turn can be utilized to generate three dimensional data-sets of the particular human individuals under investigation. Of course the data can be scaled to conform to known population characteristics such as 95^{th} percentile data from various sources such as (Barter, Emanuel, and Truett, 1957).

Shortcomings of traditional visualization approaches include:

- static approximations of human movement cannot address the dynamic nature of functional abilities
- inability to accommodate widely varying movement capabilities and different levels of total body engagement
- lack of effective means for designers to dynamically incorporate anthropometric factors into the design process

2. Methodology
Unlike the manikin approach developed by Jack[tm], in which a human-like figure is inserted into a three dimensional scene in order to be manually moved into useful positions, our research extends commercial off the shelf (COTS) software to generate real-time visualizations which in turn generate either useful three dimensional data which can be measured and inspected or abstract visualization of dynamic information such as reach or joint angle changes.

We have demonstrated shortcomings of traditional approaches toward anthropometric visualization - something understood but simply accepted as inevitable by professionals in practice (D. Wooley, personal communication, January 26, 2001). As noted by Damon (1966), " Functional reach ... is not a simple derivation of anatomical arm reach ... Functional arm reach therefore changes with each placement and motion of the body, arm, hand or fingers."

One aspect of this project is in the application of known technology to novel uses - the use of inverse kinematic techniques into the process of environmental and artifact design. The methodology used in this project for the anthropometric measurements is known and established. Computer based kinematic movement is common place today, being used in industries such as film-making and computer gaming.

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Figure 1 shows a ROM path (shown in dots) generated in this project compared to data from Dryfuss (1960). The procedure for this process consists of first normalizing three dimensional anthropometric data (in this case of a fit person) with the image used for comparison. Begin by extending the arm to coincide with traditional motion path near the leg. Then an animation is choreographed with IK to create natural movement which approximates as closely as anatomically possible the Dryfuss motion path. Since Dryfuss used a semicircle to generate his path we can observer some predictable differences between the two paths generated. As the motion is animated a white dot is generated every frame and eventually creates a unique dataset. The assumed semicircle is solid while the white dots represent the data generated with inverse kinematics which more closely approximates human motion.

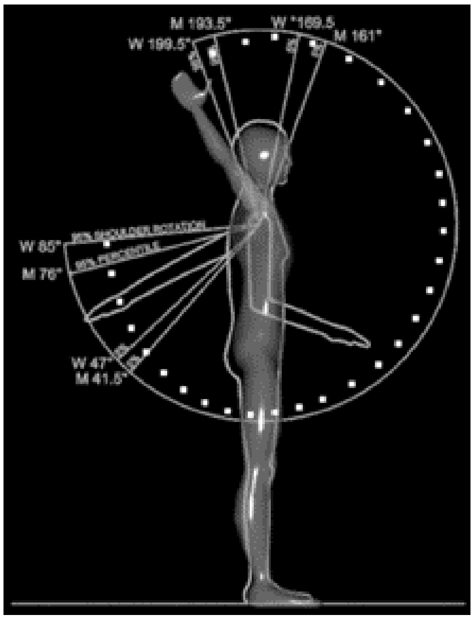

Figure 1. Computer generated motion (white dots) compared with data adapted from Dryfuss (solid line).

Anthropometric measurements of individuals, including people with disabilities can be visualized as solid surfaces which provide meaningful insights when placed in relevant contexts such as workplace environments. Figures 2 shows the development of a three dimension envelope of ROM for the right arm of a seated fit person. Figure 3 shows another set of paths which are generated, connected into paths and converted into polygonal data.

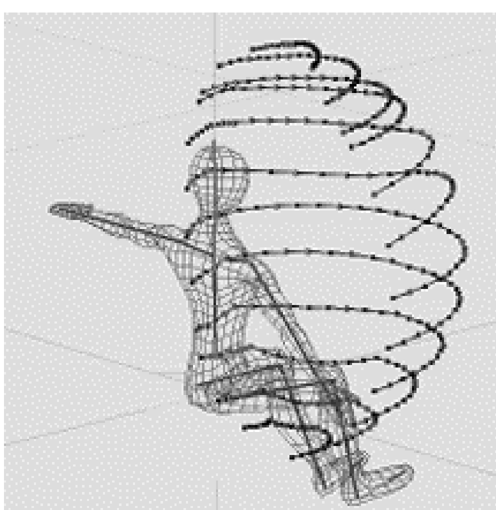

Figure 2. Right arm motion path generation.

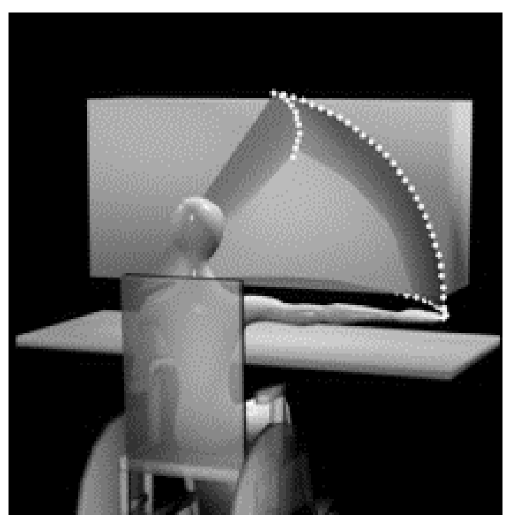

Figure 3. Solid, from motion path, intersecting cabinet.

Preliminary verification of this process comes from a comparison with Kennedy's (1964) data. In figure 4 we see a close approximation of the inverse kinematic data, represented by white dots (in this case forward motion only), and the solid lines which represent the range of motion 25 inches above the standard reference level (SRL).

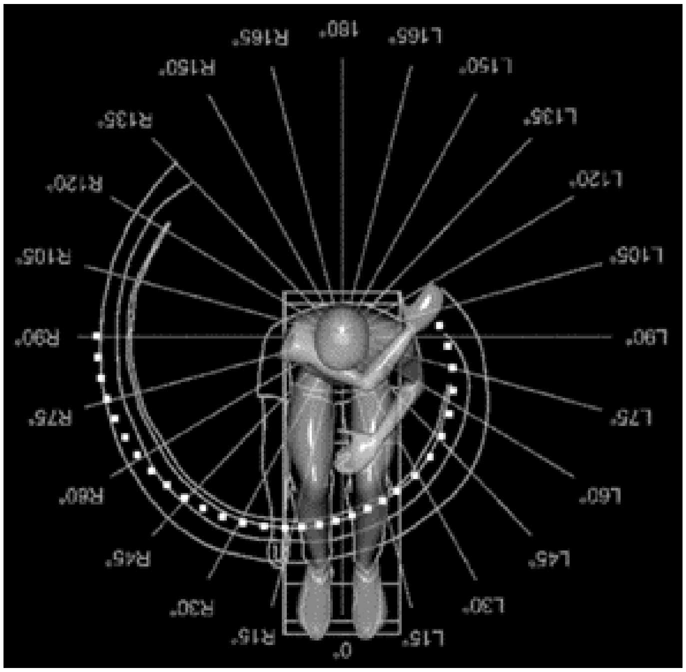

Figure 4. IK data, white dots, compared with data adapted from Kennedy's work which is shown in solid lines.

In this process degree of freedom measurements are taken from the person under study and the results are input into MIRAI^{tm} the COTS software used in this project. The biomechanical model in this study has 12 segments which includes the hands, lower arms, upper arms, shoulders, as well as head, neck, and two piece spinal cord. Figure 5 shows a session in which the DOF of the left upper arm is being manipulated.

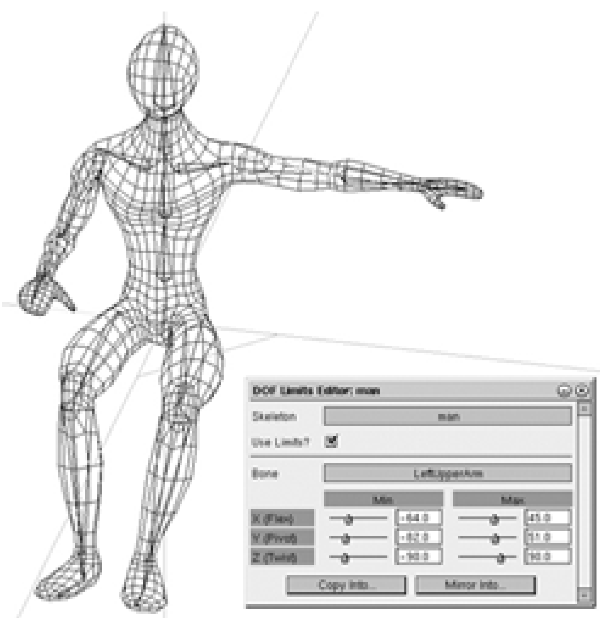

Figure 5. Input of DOF numbers for the left upper arm in MIRAI^{tm}.

Visualizations of a person with disabilities is shown in figure 6 and 7. Figure 6 shows a perspective view of person seated in a wheelchair at a typical computer workspace. Figure 7 shows the same scene from the top.

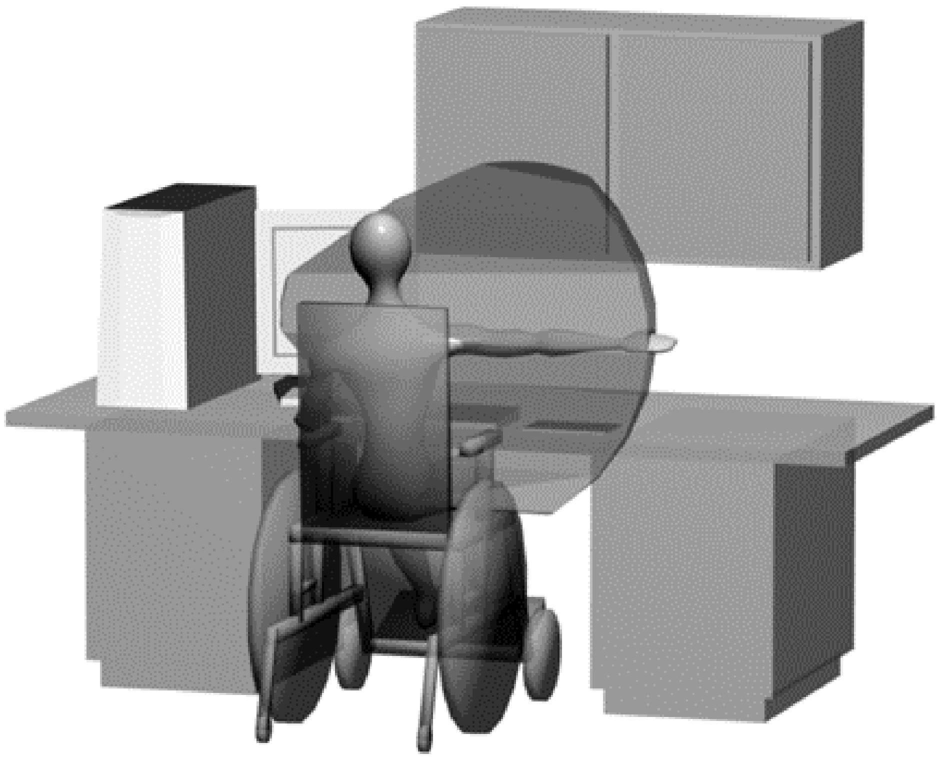

Figure 6. Perspective view of the right arm ROM envelope of a person with disabilities.

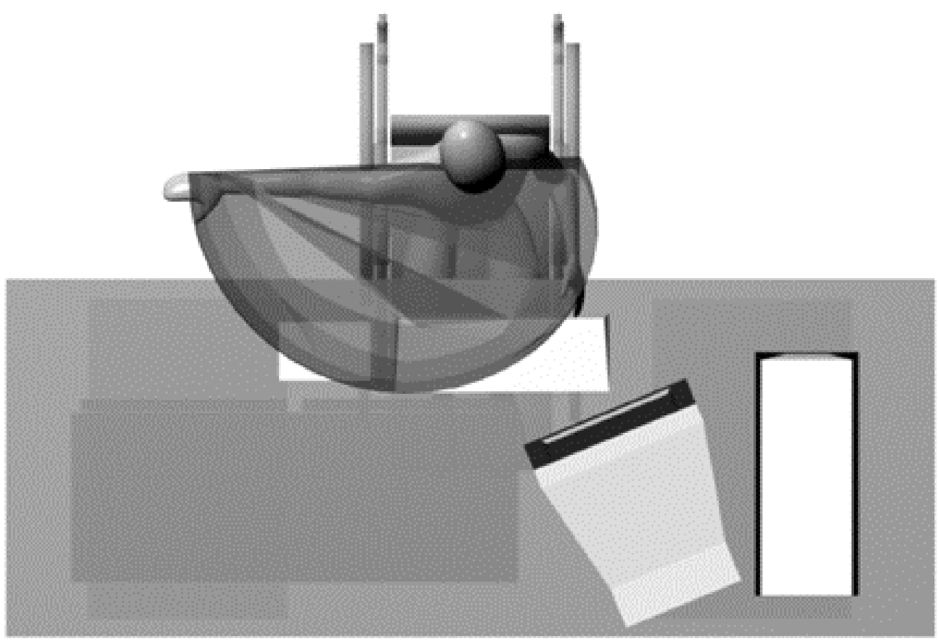

Figure 7. Top view of the right arm ROM envelope of a person with disabilities.

Figure 7 can be compared with figure 8 which is the same view of a fit person and reach envelope.

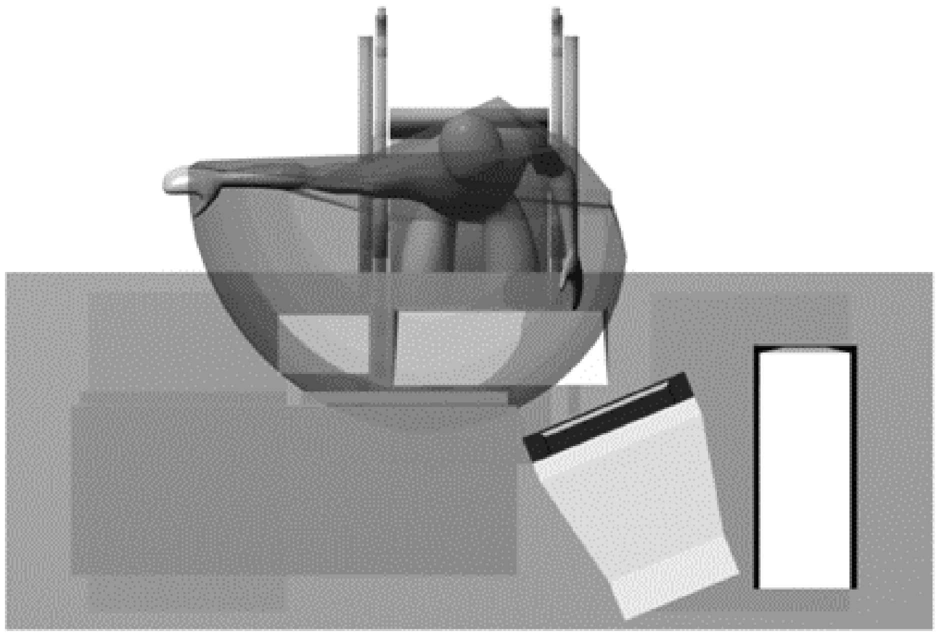

Figure 8. Top view of a fit person and reach envelope in the same environment as shown in figure 7.

Data sets can be combined to show differences as is shown in figure 9. This shows a side view and front view of two data sets, the darker smaller volume is from the same person with disabilities as shown in figures 7 and 6. This person is a 41 year old female with osteoarthritis. The large lighter region shows a 95th percentile fit person.

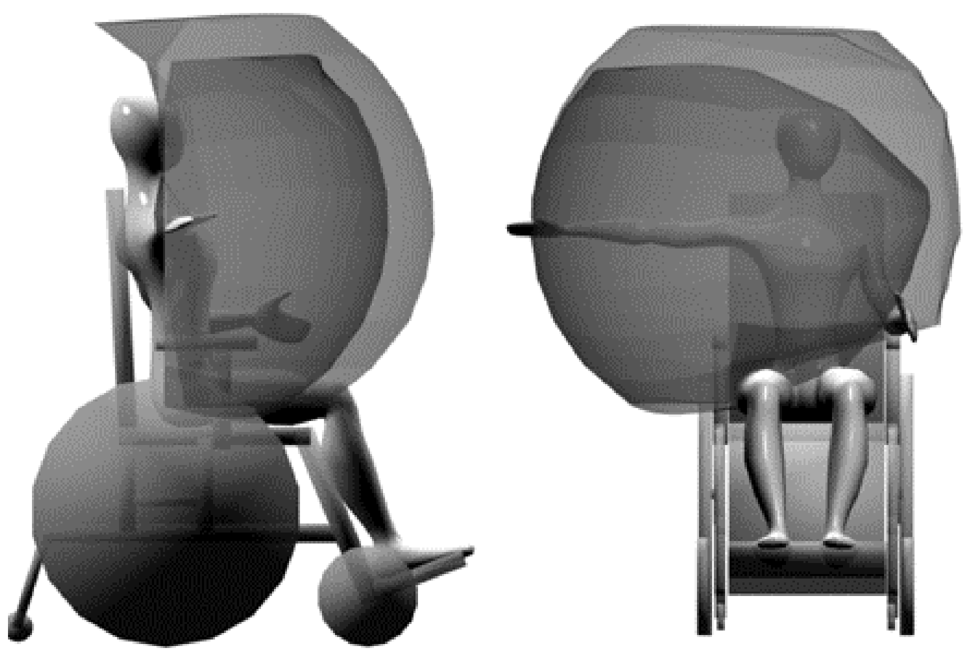

Figure 9. Comparison of two range of motion data sets.

As mentioned above, the project is also examining the visualization of different levels of physical engagement for the same task. Specifically torso, shoulder and elbow movements for the same general motion. Figures 10, 11, and 12 show the increased range of motion paths as each factor is taken into account, shown in comparison with data based on the work of Farley, Squires and Goel (1969). This provides more realistic movement information.

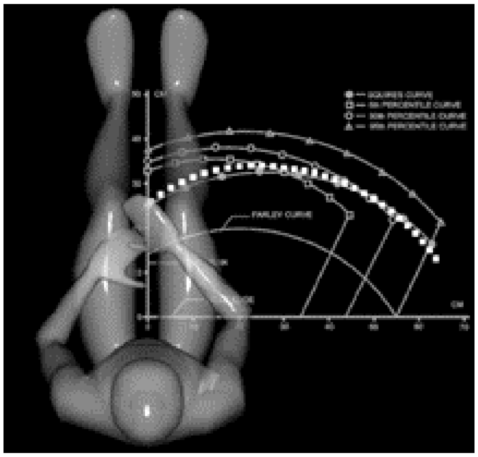

Figure 10. Path with elbow movement only, comparison data after Farley.

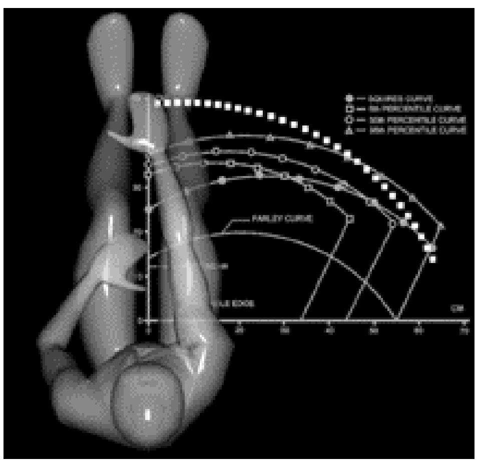

Figure 11. Path with shoulder movement included, comparison data after Farley.

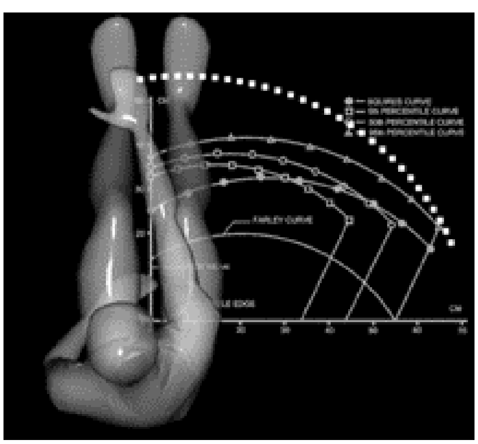

Figure 12. Path with torso movement included, comparison data after Farley.

3. Conclusions and Future Work

Much of the inaccuracy and incompleteness in traditional diagrams is caused by assuming the elbow, shoulder or torso to be fixed during motion which conceals the overall joint DOF effects. As the motion paths in figures 10, 11 and 12 show, the effects of such DOF information are very important for the visualization of anthropometric data.

Given proper anthropometric measurements, computer-based three dimensional anthropometric models provides an infinitely adjustable method of representing various motion capabilities and characteristics. The environmental fit of artifacts and environments to specific (and generic) human capabilities can be assessed by visualizing the three dimensional reach envelope. Data generated from computer models can be utilized in a CAD environment for real time decision making during the design process.

Future project plans include additional validation of visualization results through the use of a motion tracking device which records a trace of position during movement, such as those available from Ascension Technology Corporation. This data would be compared to that generated with computer models and DOF constraints taken from the subject who provides data from the motion tracking device.

Tighter integration of the visualization techniques with the design process will also be pursued with emphasis placed on creating automatic and procedural routines for generating known types of data sets, such as ROM envelopes for any particular individual, as well as procedures to generate ROM datasets for any specific type of task such as operating various types of hand tools.

Information from static strength analysis also must be incorporated into the CAD environment in order to ensure functional abilities are correctly understood.

4. Acknowledgements

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