Visualization of Human Motion in Design

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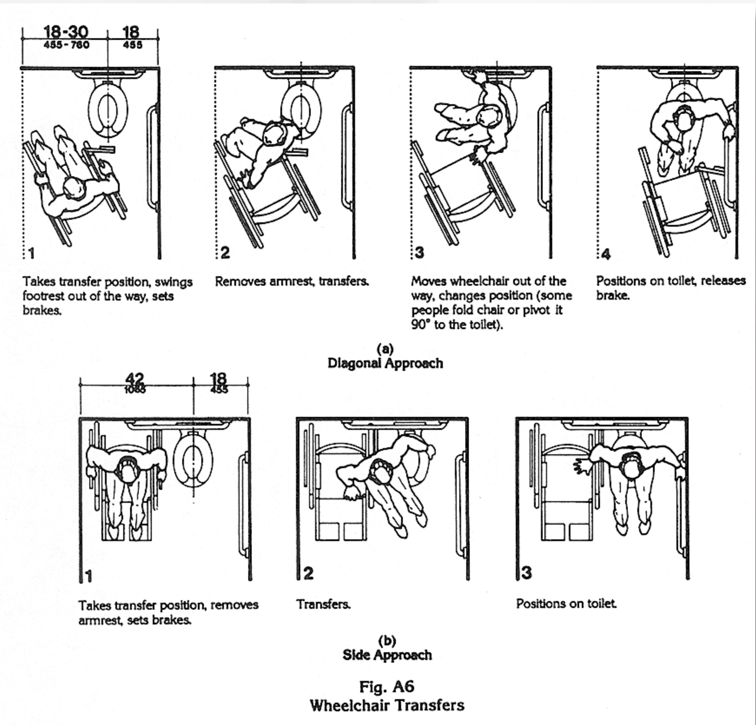
Introduction

Research Questions:

1.) How can designers incorporate ergonomic data into their workflow?

2.) How to visualize this data in a way that benifits the design process?

Design requires extensive knowledge of human ergonomics. Legal documents such as the Americans with Disabilities Act represent human ergonomics as two dimensional drawings. These drawings have been used for decades, and although the thechnology and workflow of designers have vastly changed, the method in which ergonomic data is represented has not. With the exception of proprietary and expensive human simulation models for government and corporations, designers lack a system in which they can test their computer model against anthropometric data.

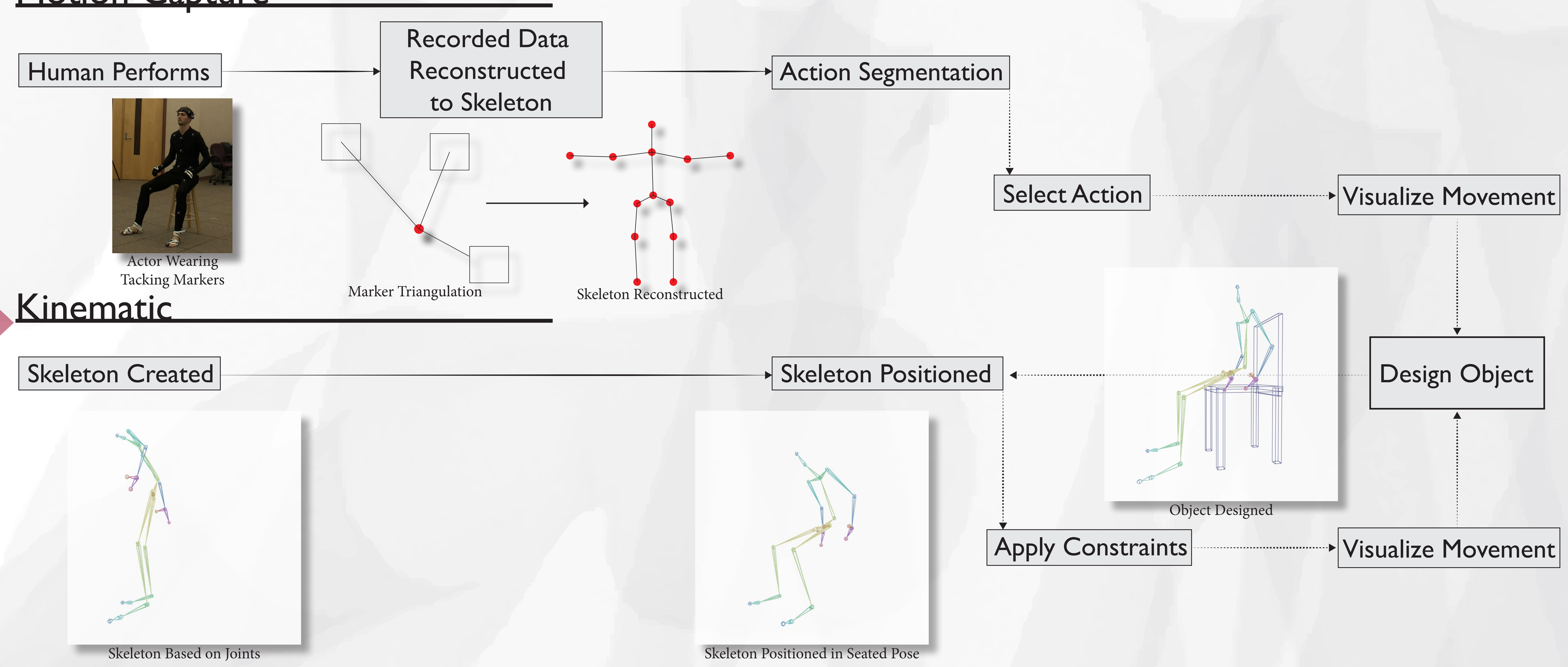


Excerpt From ADA Standards book on how a handicapped person moves to a toilet.

Research Objective:

The objective of this research is to demonstrate a method for incorporating human ergonomic data in the design workflow by leveraging the capabilities of accessible applications.

Methodology



Complexity

Inverse Kinematic System

Given the homogenous transformation T_n^0 which describes the position and orientation of the nth end effector frame with respect to the base frame, then transformation A_i that describes the location and orientation of the ith frame can be given by:

$$T_n^0 = A_1(q_1) \cdot A_2(q_2) \ldots\ldots A_n(q_n)$$

This results in twelve non-linear equations with n unknown variables $(q_1, q_2, .., q_n)$. Thus if the above equation is under-constrained, such that the number of independent quantities specified by T_n^0 is less than n, then there are an infinite number of values/ solutions for the joint variables $(q_1, q_2, .., q_n)$, as for every possible value of a redundant joint variable, a new set a solutions can be formed.

Motion Capture System

For Motion Capture we look at an Eight Infrared Camera system tracking 52 Markers at 120hz. The recording of the motions is O(1) as the cameras record all of the view. The reconstruction of the markers is where the complexity increses. The program needs to triangulate each point through multiple cameras. This complexity can vary on the internal algorithm.

Forward Kinematic System

Given the homogenous transformations A_i which describes the position and orientation of the ith joint frame with respect to the (i-1)th frame and which is only a function of joint variable q_i i.e.

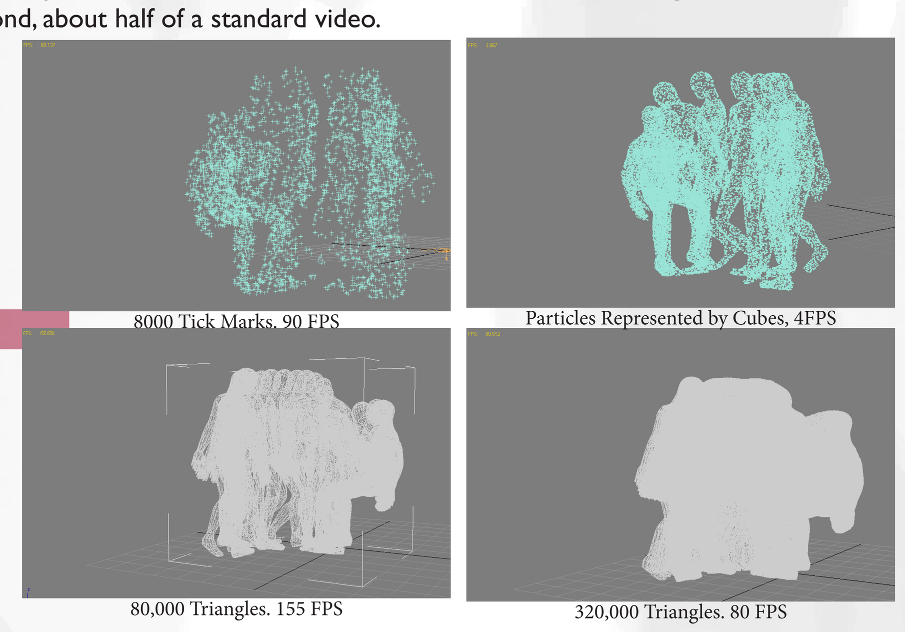
$$A_i = A_i(q_i)$$

then the transformation T_n^0 that describes the location p_n^0 and orientation R_n^0 of the nth end-effecter frame with respect to the base frame can be given as:

$$T_n^0 = A_1(q_1) \cdot A_2(q_2) \ldots\ldots A_n(q_n) = \begin{pmatrix} R_n^0 & p_n^0 \\ 0 & 1 \end{pmatrix}$$

Thus for an added number of joints/ degrees of freedom n, the computational load for a given set of joint variables increases.

Within the modeling software the frame per seconds of the model play a large role in the efficacy of the visualization. A frame rate that is too low results in a useless tool. For simplicity we can assume a comfortable frame rate for modeling would be 15 frames per second, about half of a standard video.



8000 Tick Marks, 90 FPS — Particles Represented by Cubes, 4FPS — 80,000 Triangles, 155 FPS — 320,000 Triangles, 80 FPS

Analysis

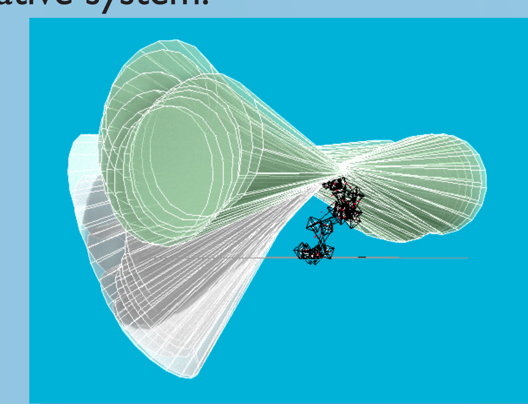
The two methods of visualization presented are points and meshes. These methods represent a movement occurring over time in a single form. The two types of visualization aid in design differently depending on the resolution of the movement. If a high resolution is used, the movement becomes a single envelope describing the domain of the movement. A low resolution gives a visual understanding as to how the human interacted with the chair. Although impossible to display here, the translation of the visualization from three to two dimensional media presents a different dynamic between the types of visualizations. While on the computer the point cloud at a low resolution would give an understanding of human interaction with the object, the lack of depth on two dimensional media yields a visualization representing the domain of the movement. The mesh visualization was best represented in two dimensions using transparent materials for rendering. The overlay of the materials maintains the interaction understanding at low resolution whereas the solid mesh at the same resolution becomes a domain.

These visualizations give valuable insight to the challenges in three dimensional ergonomic diagrams. While the visualizations use motion capture data, they show the efficacy of having multiple visualization systems when kinematic models are used.

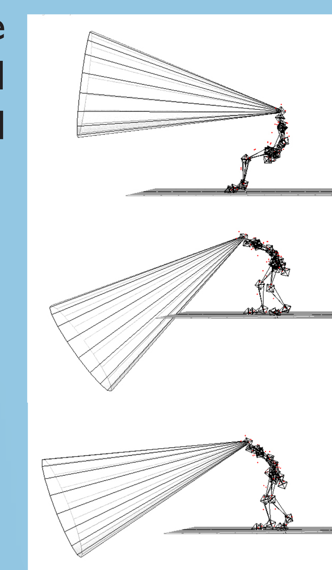
Future

The presented results use motion capture data as the input for human movement. The two techniques of visualization applied translate to a model in which the input was a human kinematic system. The combination of motion capture and kinematic systems in a design workflow provide the designer with an incredible knowledge of human movement in relation to their work.

While the current work deals specifically with the human envelope, the incorporation of three dimensional modeling tools into the design workflow not only allows for the incorporation of human motion visualizations but also allows for an easy integration of other factors. As design works with many different factors such as color, noise, temperature, etc., the integration of psychological and physiological factors would allow for a more versatile and informative system.



Visual and Auditory Field Visualization



Binocular Domain Viz

Although the examples of visualizations shown are based on a chair, the application of the work is not limited to mainstream industrial design. The integration of human simulation models in NASA and engineering is nothing new. However, these simulations lack a simplified visualization system that allows for diverse application. Designers and Architects working in any spatial design field including but not limited to the designs of jails, submarines, and on-terrain vehicles could benefit from a designer controlled and dynamic system for human movement visualization.

Acknowledgement

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References

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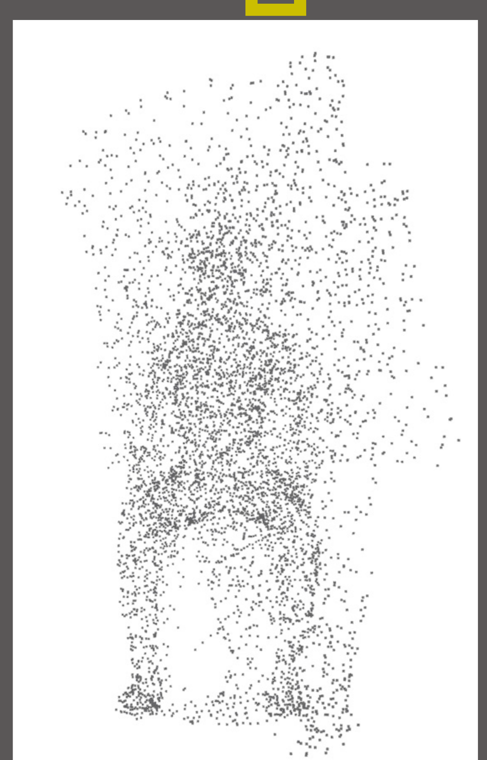
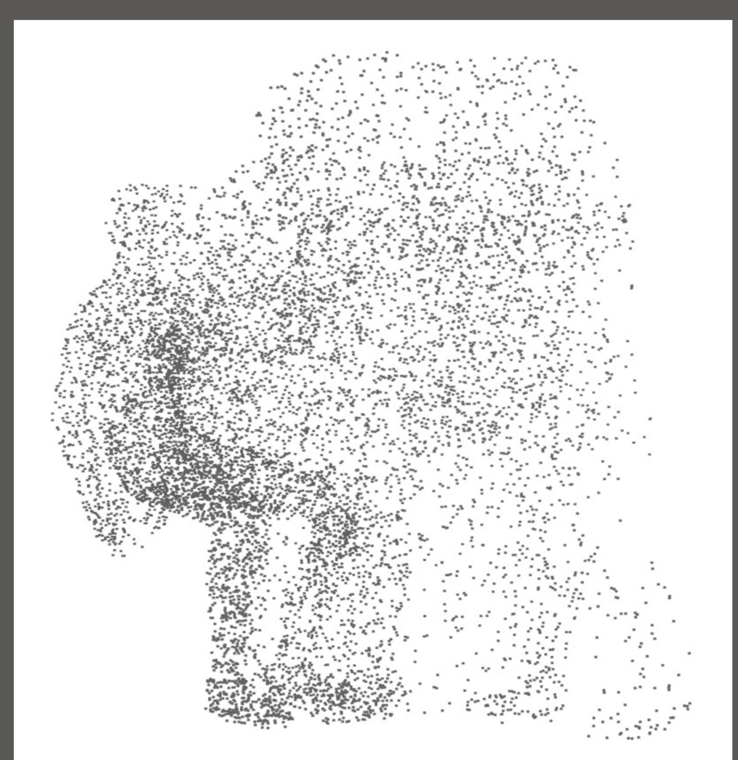
[4] M.W. Spong, S. Hutchinson, M. Vidyasagar, "Robot Modeling and Control", John Wiley & Sons, Inc., 2006

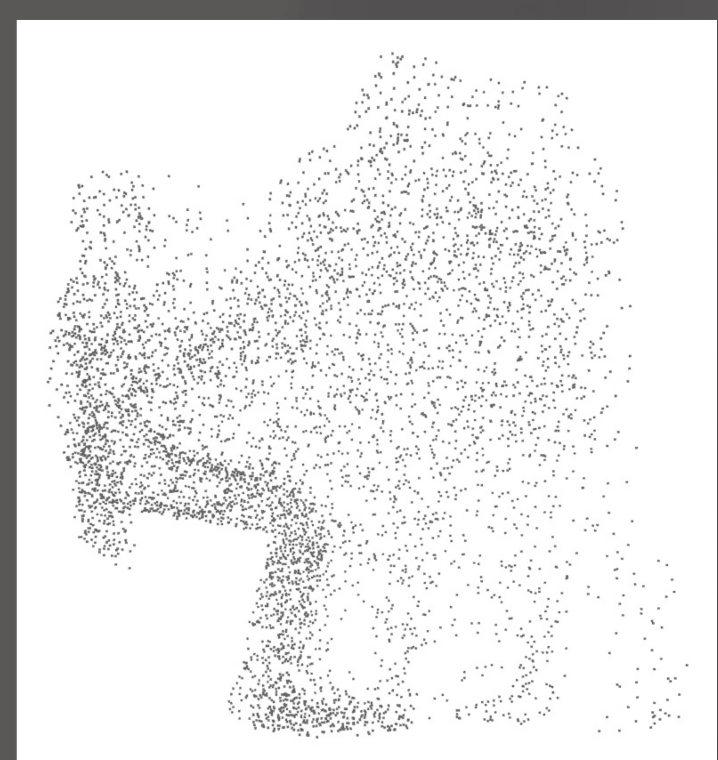
Results



Point Cloud. Front View. 15 Segmentations 1,000 Points

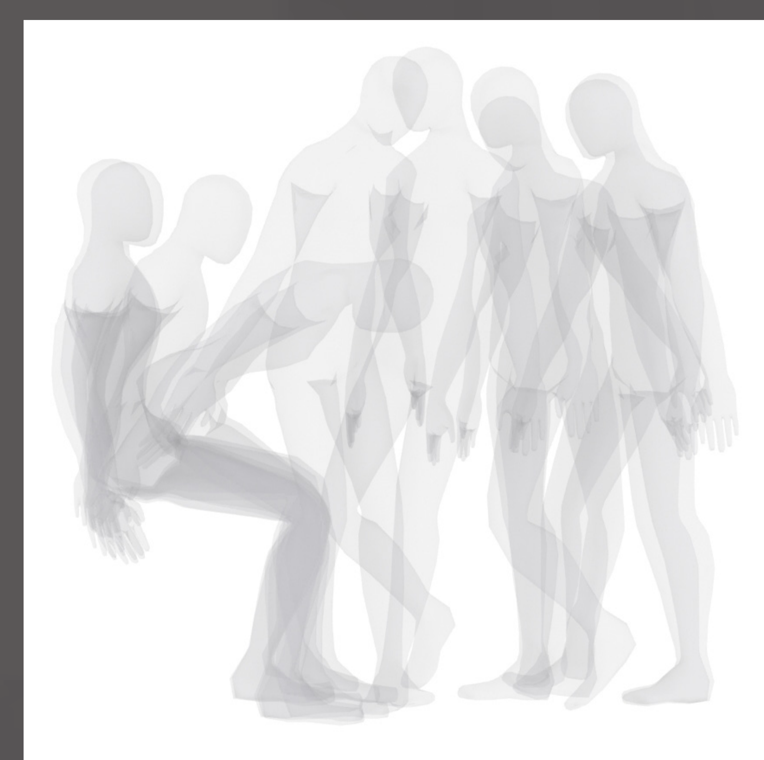


Point Cloud. Perspective View. 15 Segmentations 10,000 Points

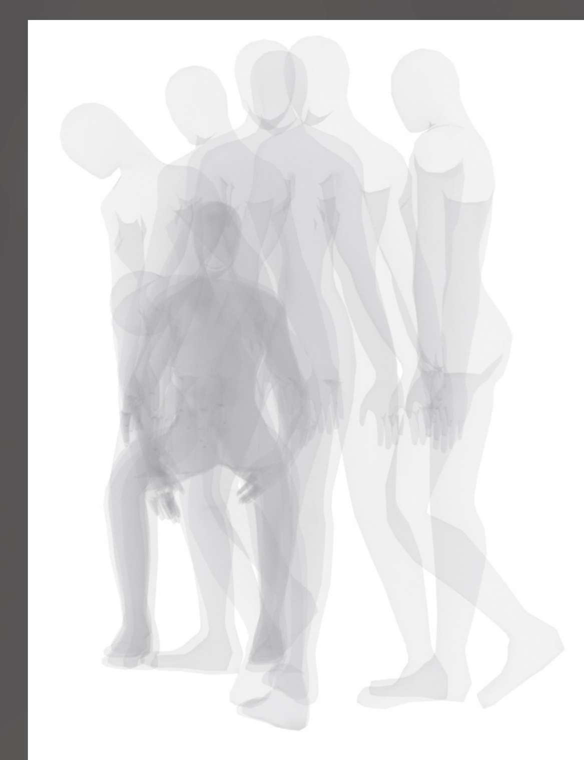


Point Cloud. Side View. 15 Segmentations 1000 Points

Mesh. Side View. 50 Segmentations. 160,000 Traingles



Mesh. Side View. 25 Segmentations. 90,000 Traingles



Mesh. Front View. 25 Segmentations. 90,000 Traingles

Mesh. Top View. 50 Segmentations. 160,000 Traingles