The Anthropometric Measurement and Modeling Project

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Abstract

Disability is a product of the interactions between individuals and the environment they inhabit and the products they utilize. Disability is located on a continuum from enablement to disablement. Human physical characteristics as well as environmental factors will locate an individual on that continuum. The degree of disability or enablement will fluctuate, depending upon the attributes of the environment and the artifacts located there.

The ability of designers and architects to create environments and products that enable all people is directly tied to their ability to:

1. understand the abilities and constraints of the human body and,
2. model the physics of the body's interactions with artifacts and spaces.

This project is developing an anthropometric measurement protocol and computer-based design tools focusing on people with disabilities and the aging. The areas of interest for measurement are guided by real-world design needs. The measurements generated are translated into three-dimensional datasets compatible with commercial off the shelf software extended by the programming of additional scripts, functions, plug-ins, behaviors, etc.

1 Introduction

Disability is a common condition. There are currently approximately 43 million people within the USA with disabling conditions that interfere with their life activities (McNeil, 1993). In the past four decades the prevailing wisdom about the cause of disability has undergone profound change. Previous models of disability that viewed disability as a pathological process are being replaced by models in which disability is seen as an interaction between the characteristics of the individual with disabling conditions and the characteristics of their environment. The level of disability is not determined merely by levels of pathologies, impairments or functional limitations. Instead, it is a function of the extent to which the social and physical environment is accommodating to their particular needs.

Inadequately or poorly designed environments and tools of daily living impose barriers to the individual with a disability, which need to be addressed in order for people with disabilities to lead full and purposeful lives. These can be addressed by:

- Defining the physical characteristics and attributes of the people for whom they are being designed
- Provide these data in a form that is compatible with modern design tools and is relevant to the individual who wishes to use it.

Defining disability as an interaction between the person and their environment has played a key role in influencing the political system, through its role in designing public policy, to develop and implement legislation to address the barriers that the physical environment presents to persons with disabilities: barriers which discriminated against persons with disabilities and prevent them

from leading a full and inclusive life. Perhaps the most encompassing of all this legislation is the Americans with Disabilities Act of 1990 designed to improve the prospects of people with disabilities to achieve a fuller participation in every domain of human activity.

The Americans with Disabilities Act (ADA) is a federal civil rights act enacted in 1990 prohibiting discrimination against people with disabilities. Discrimination in employment, access to places of public accommodation, services, programs, public transportation and telecommunications is prohibited by this law. Physical barriers that impede access must be removed whenever they exist.

One component to the removal of these barriers is through the construction and use of well-designed environments and artifacts. To achieve good design, in terms of both architectural and product design requires a solid understanding of the physical abilities of the population of people for whom the design is directed, i.e. a user-centered approach. One way that this can be achieved through the collection of anthropometric data and the application of those measurements to the design of consumer products, work places and equipment. Anthropometry describes the physical characteristics of humans in terms of attributes such as body size, reach and functional reach measurements, arm and hand strength measurements and field of vision measurements.

In order for the use of anthropometric data to be effective it must be appropriate to the design/use context and, more importantly it must be descriptive of the target user population. The first condition deals with the issue of static versus dynamic anthropometric measurements. Static dimensions - those "taken on the human body with the subjects in rigid, standardized positions, are easily obtained and readily applied to equipment design" (Damon 1966) are readily available in numerous reference works and texts, such as (Dreyfuss 1967; Panero 1979; Pulat 1992 and Pheasant 1986). However, these data sets, because of the way in which they were obtained, are not relevant to any specific design problem. Functional arm reach, for example, will change with each new placement and motion of the body or any of its segments, such as arms or fingers. The data required to specify specific design problems - dynamic dimensions, those "taken on the human body at work or in motion" are needed for a fully functional design environment (Damon 1966) .

Another factor, with regard to appropriate data representation, are the liberties taken in characterizing some measurements. A widely used illustration of normal and maximal arm reach areas was constructed by showing two intersecting semicircles in which elbows, shoulder and hand joints are assumed to be fixed and rotating through one plane during motion. The widely used Farley's data sets are similar to this kind of data (Farley 1955). An illustration of such traditional data (Tilley 1993]) superimposed with data generated via a computer generated inverse kinematic model is shown in Figure 1.

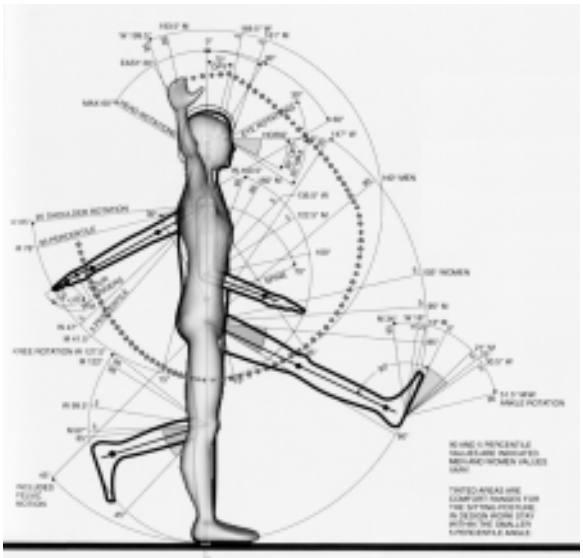

Figure 1. Comparison of traditional ergonomic data and computer generated modeling (shown with dots).

For anthropometric data to be useful to design for the disabled it must be collected from the target population to be descriptive of that population. Presently, the Army ANSUR data is the primary default human anthropometric database, representing typically young, fit people, which is not representative of the general US population let alone the population of persons with disabilities. This limitation in the data available to designers, architects, healthcare professional and policy makers presents a fundamental hurdle to the appropriate design of any products and environments or the creation of legislation to remove the barriers faced by people.

To illustrate this, the ADA has a uniform nationwide mandate that ensures accessibility regardless of local attitudes. The Architectural and Transportation Barriers Compliance Board (Access Board), whose responsibilities were significantly broadened as a result of the implementation of the ADA, is an independent Federal agency responsible for developing accessibility guidelines for buildings, facilities and transit vehicles.

The Access Board established minimum technical requirements for the design and construction of buildings and facilities when it published its Accessibility Guidelines (ADAAG) in 1991. These guidelines were written with a clear intent to increase the level of accessibility in the built environment in new construction, alterations and existing facilities. The guidelines, intended to provide the basis of design standards for living and working spaces that would accommodate people with disabilities, were largely based on the results of anthropometric research in human body size and

reach obtained in the 1960s and 1970s.

Advances in medicine and rehabilitation techniques and the rapid proliferation of technology, has increased the numbers of persons with a wide variety of disabilities entering the mainstream of American life. It is also important to note that the traditional concept of the disabled population is on the doorstep of a dramatic shift in its make-up as the population ages.

Many of the original design standards were based on seated measurements of adults without disabilities. This model does not define the population of persons with disabilities.

Bradtmiller (1997) prepared an extensive bibliography of "Anthropometry for people with disabilities" for the U.S. Architectural and Transportation Barriers Compliance Board. In it he described that there existed a large body of anthropometric data on more than 11,000 persons of every age and a wide variety of disabilities. However most of the studies were conducted on specialized populations, many of them foreign, and therefore has very limited application to the general U.S. population of persons with disabilities. Dimension definitions and measurement techniques varied from study to study and, in many cases, samples were very small. He concluded that while there was a great deal of existing anthropometric data, any attempt to combine them into a useful database would be futile.

This project is developing the basic protocols to address this need for greater information and knowledge on issues of the functional abilities of people with disabilities, to improve access and the design and re-design of objects of daily living through the use of computer based modeling techniques, developed to be compatible with existing computer based design tools and environments.

2 Objectives

In general terms, the objectives of this project are to collect anthropometric body dimensions for a sample population of people with disabilities, distributed amongst the selected categories of pathologies. This data will then be used to create three-dimensional computer datasets, which will be used in an interactive computer design environment. These 3D datasets, when used in this way will enable an iterative design process that factors in relevant aspects of a particular disability, for example, strength capabilities, to allow the design of environments and artifacts with the least demanding of physical exertion.

In a CAD environment, datasets used to create an articulating figure, modeled with range of joint motion constraints as well as key strength characteristics, can interact with a device such as a door handle to determine if the chosen design is effective and efficient in its use. This information can then help guide the design or re-design of objects of daily living to maximize functional ability while minimizing unnecessary physical exertion.

3 Dynamic Environmental Modeling

One aspect of this project involves the determination of the three-dimensional boundary envelopes that will characterize the spaces in which a person can reach and manipulate objects. Animated visualizations can be made in near-real time using wire-frame mode and sparse data or fully rendered visualizations can be made for playback. Data can be queried for exact location and volumetric attributes.

The following sequence of still images illustrates the creation of visualizations concerned with the reach characteristics of a person in a wheelchair as they interact with a simple counter and cabinet environment. First, inverse kinematics is used to trace an outline of the reach envelope, which is indicated with white dots as shown in Figure 2.

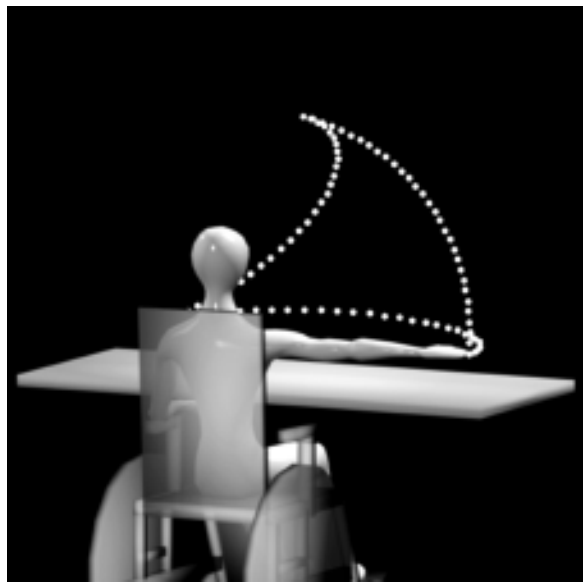

Figure 2. Linear reach outline - indicated by white dots.

Next, a 3D envelope is developed as indicated by the gray shaded area bounded by white dots in Figure 3. The points of this volume are defined in three-space (xyz) and can be used for measurement and placement of surrounding objects. This shape can also be queried for volumetric information.

Finally, the reach envelope can be intersected with objects in the environment to determine the precise areas of interaction and utility. The union of the reach envelope and cabinet exterior is shown in Figure

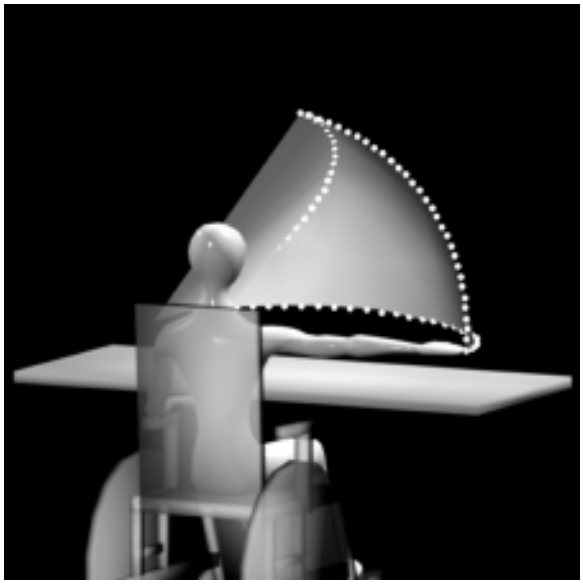

Figure 3. Three-dimensional reach envelope shown in gray shaded area surrounded by white dots.

4. Other options will include the other standard Boolean operations so that objects and spaces can be inspected and measured in a number of different ways.

This paper and visual support materials may be found at:

www.sarc.msstate.edu/~wwang/ergo/acadia/

4 Future Work

The project will include a number of other longitudinal components which will utilize the data and information developed to educate and provide guidance to people with disabilities, insurance companies, policy making bodies and clinicians. As a more realistic assessment of people with disabilities emerges, better planning can be made regarding future physical needs and therapy decisions as well as public policy initiatives.

Acknowledgements

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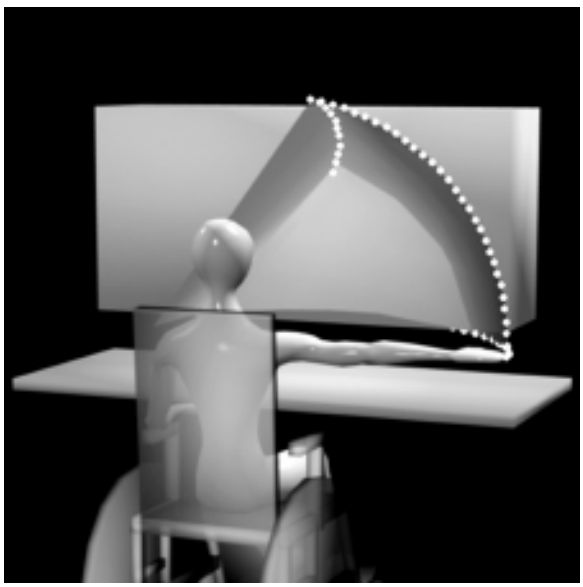

Figure 4. Union of reach capabilities and cabinetry exterior.