Anthropometric models of children

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ABSTRACT

The objective of the work presented in this paper is to create a complete database of Anthropometric Models of Children, which can not only describe the anthropometric attributes of the individuals, but the functional abilities and growth behaviors as well. This work also includes a prototype system, which is being used during an assessment session to automatically gather the anthropometric and functional information of the subject and incorporated it into the population data of the model database.

1. INTRODUCTION

Three-dimensional simulation of anthropometrically correct human figures has been researched extensively (Badler et al, 1979; Bapu et al, 1981; McDaniel et al, 1988; Badler et al, 1993), but this research has all focused on full grown male and female populations. In this paper we present the Anthropometric Models of Children database which is based on the anthropometric data gathered for the Consumer Product Safety Commission in 1977 (Snyder et al, 1977). This model database currently contains accurately scaled body segment dimensions for children, ages 2 through 18, at the 5th, 50th, and 95th percentiles of the sampled population. Additionally, the models in the Anthropometric Models of Children database are compliant with the standardization efforts of the VRML Humanoid Animation (HANIM) working group of the VRML Consortium (HANIM 1997). The goal of HANIM is to create a standard structure for humanoid figures, to allow animation data sets and kinematic control systems to manipulate a variety of humanoid models. Additionally these models are able to be controlled by the body object bitstream of the MPEG4, which was defined by the Synthetic Natural Hybrid Coding Ad-Hoc Group on Face and Body Animation (SNHCFBA 1998). Compliance and integration with these standardization efforts is especially necessary for research efforts relating to the rehabilitation and disability fields, because there is a smaller population that directly benefits from developments in these areas. It therefore becomes important that researchers try to "piggyback" their efforts onto research developments and standardization efforts, which have a broader population benefit and adapt those developments to serve the needs of the smaller population of individuals with disabilities.

2. BACKGROUND

2.1 Consumer Focused Design

This research began as a small part of a consumer focused design program investigating methods of product design that are adaptable to consumer needs, are cost effective and exploit new methods of rapid prototyping. This design program included exploring ways in which virtual models and computer visualization software could be used to reduce the cost of designing rehabilitation devices. Part of this work focused on creating

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software tools and resources for designers, which would assist them in the creation of new rehabilitation devices.

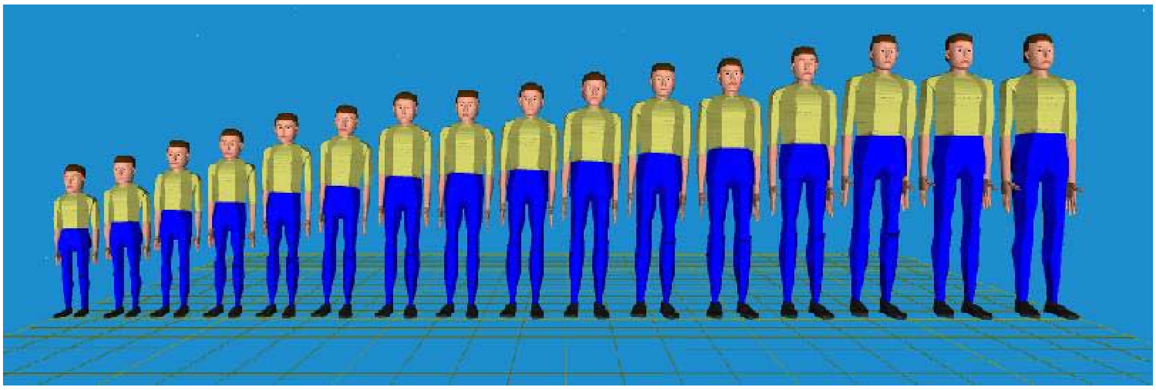

Figure 1. *The Anthropometric Models of Children, Ages 2-18.*

Since there are a diverse range of physical abilities from one user to the, there exists a need for designing devices which are user specific. This design cycle is complicated by the complexity of the device and the small market size as well as numerous biomechanical factors that need to be considered. The techniques of virtual design and rapid prototyping are ideally suited for assessing these factors as well as rapidly designing and manufacturing one-of-a-kind rehabilitation devices.

2.2 Device Generation from D-H Parameters

The initial work of this consumer focused project concentrated on a system that would allow the rapid creation of virtual devices based on kinematic specifications of the device. The system allows the designer to accomplishes this by having him input the Denavit-Hartenberg parameters (Denavit and Hartenberg, 1955) of the device they are prototyping. The Denavit-Hartenberg notation is a common kinematic protocol used by designers for defining a device's movements. After the designer has inputted the Denavit-Hartenberg parameters the system automatically generates a 3-D graphical model of the device (Figure 2) that can be manipulated by the user.

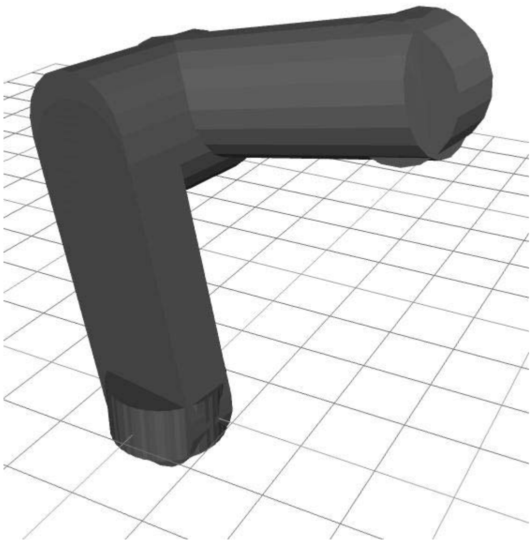

Figure 2. *A virtual device automatically generated from D-H parameters.*

An additional feature of the system is that it also allows the designer to define a set of external inputs to control the movements of the multiple joints of the device or to interact with the device using a Cartesian based control method. A Spaceball 6DOF isometric joystick, which has proven effective in controlling rehabilitation devices in the past (Wisaksana et al, 1995), allows the designer and user to experiment with controlling the virtual prototype device. The different degrees of freedom of the virtual prototype device can also be controlled with keyboard inputs. The model of the device can also be altered interactively by the

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designer, so that he can customize it according to verbal feedback from the user and the evaluation process. The initial software system successfully facilitated the design process of rapid prototyping by:

- allowing experimentation with different scenarios of controlling a mechanism
- allowing quick implementation of control scenarios designed by others
- enabling the designer to discover possible design flaws before actual fabrication of a mechanism
- making the design of "one-of-a-kind" control scenarios an affordable possibility, because of the ability to change the control mapping in seconds
- making the design of "one-of-a-kind" mechanisms an affordable possibility since unnecessary time and resources must not be spent on fabricating physical prototype devices

2.3 Anthropometric Customization of D-H Parameters

The final stage of the virtual device creation system was to include an "anthropometric adaptation" component, which could alter the D-H parameters based on the anthropometric information of a particular user. For this stage of the work we had proposed to use the ™JACK software application, which allows ergonomic and anthropometric simulation of human figures. The JACK human simulation application has been underdevelopment for almost 20 years (Badler et al 1979) at an estimated cost of over 15 million dollars. It is widely considered to be the most comprehensive software for graphical human modeling and simulation. However, since most of the funding for the development of JACK was provided by NASA and the United States Army, the anthropometric data which was incorporated into the JACK human simulation system was entirely based on studies which were gathered from adult male and female populations.

3. METHOD

3.1 Anthropometric Data of Children

Due to the deficiencies of the available human simulation software, the focus for the final stage of the virtual device creation system need to be changed. After a review of previous work we discovered that there was an obscure SAE study (Snyder et al, 1977) done in the mid-seventies which gathered anthropometric data for children for the purposes of design safety in automobiles.

However the information from the study was only available in journal form, so we were required to manually scan in each page of the 200 plus page study and evaluate those image files with optical character recognition software to extract the anthropometric information of the studied populations. Since optical character recognition is by no means an exact science, the database was sequentially verified with a custom designed piece of software, which examined the information in a number of ways to insure the integrity of the information.

The data of the oldest population set was first compared with the anthropometric data of the JACK system, to insure that none of the information deviated from a set of preset norms. In the event the data did vary, the original document of the anthropometry study was manually examined to determine the proper value of the anthropometric table cell. Once the oldest population set was verified, the second oldest population was put through the same procedure, however this time the oldest children population data set was used as the baseline for evaluating the preset norms, instead of the JACK data set. Each population age range was recursively verified using this method.

3.2 Extrapolation of Missing Data

In some cases, we were not able to directly transfer the anthropometric data from the original anthropometry study. This was due to a lack of standards in anthropometric assessment. For example, in the case of the hand, anthropometric information on the thickness of the hand was not gathered, so this information was estimated using the thickness of the index finger, thumb and wrist as control variables. Only four anthropometric values needed to be estimated in this manner.

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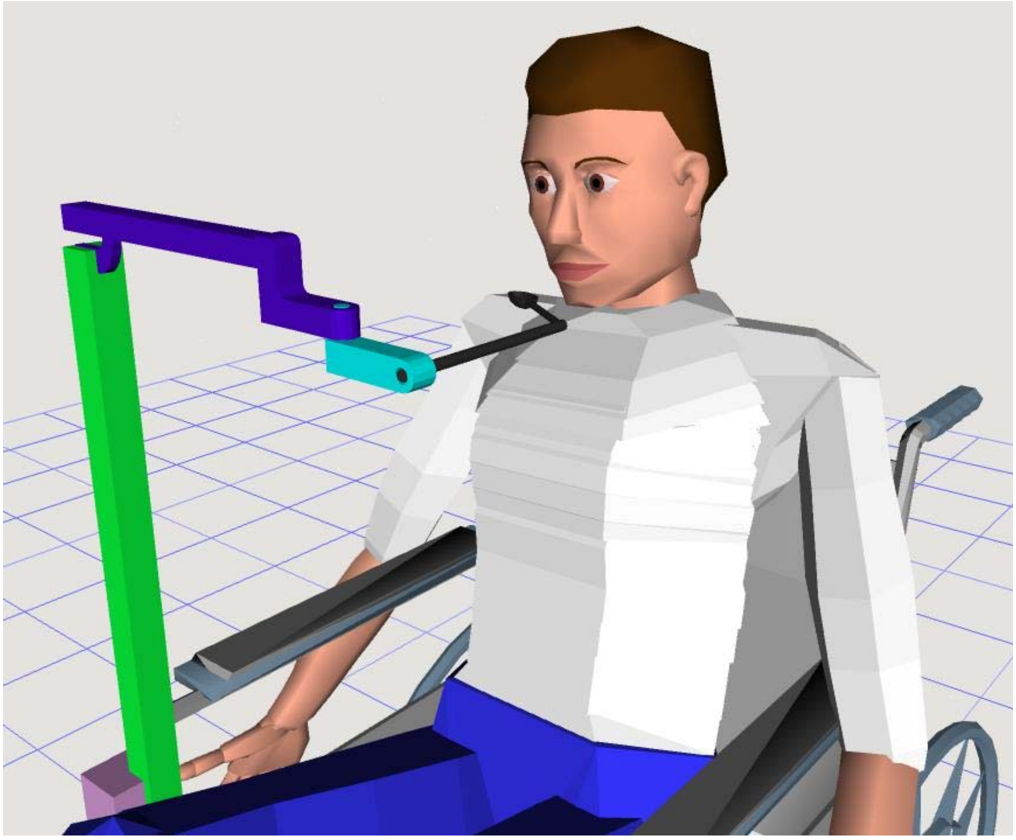

Figure 3. *An anthropometric model of a 14 year old child with the Magpie feeding device.*

4. MOTIVATION

4.1 Rehabilitation Aids

The first implication of this research is in the design of rehabilitation aids for children. A major consideration in the recommendation of rehabilitation aids for children is the amount of usability a child can get out of a device. The major disadvantages of devices, which are currently on the market, are their inability to be readily adapted, their long manufacturing time and their high cost. To avoid these problems in the future, a method of designing and fabricating rehabilitation devices has been proposed that attempts to separate the user interface design from the supporting features design (Orpwood 1990). The fundamental assumption of this method is that most of the supporting features can be acquired from conventional design techniques, whereas the user interfaces must be customized for each individual. Our research project has adopted this methodology and attempts to help the designer in identifying the configurable and extensible features of a device by enabling them to interact with a 3D graphical model of both the device and the child. By having the designer experiment with virtual computer models, as opposed to the costly and time-consuming fabrication of physical prototype models, this approach reduces the cost of device design and production. Additionally, an anthropometrically correct model, that can be interactively aged, allows a designer to better visualize the consumer of the rehabilitation device they are designing. The Anthropometric Models of Children allow the designer to predict how many years a device will be ergonomically usable by a consumer and enables the designer to alter the design of the device so that it will be more adaptable to the consumer's aging. The child models also help the designer realize what aspects of the device design can be fixed and which aspects need to be variable from user to user. Anthropometric alteration also helps the designer to visualize which components need to be variable as the consumer naturally changes over time, whether it be by natural aging or due to the effects of their disability.

4.2 Telerehabilitation

A second area this research has implications in is the field of telerehabilitation. The field of telerehabilitation has emerged over the past few years, as telecommunications and bioinstrumentation technologies have advanced and cost of those technologies has fallen. Bioinstrumentation can allow qualitative and

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quantitative information to be gathered about the child's physiological activity during a therapy session. This information can then be transmitted to a doctor, physical therapist or clinician at a remote site for diagnosis and evaluation. In this venue, the Anthropometric Models of Children database allows the proper body model to be chosen for a child and it provides an abstraction by which body animation parameters can be extracted. Those body animation parameters can then be encoded in a standard MPEG4 bitstream, transmitted to the remote site, decoded and reanimated for the individual who is monitoring the therapy session or making a diagnosis of the child's condition. By creating an abstraction between the definition of the body and the data stream which controls that body, the Anthropometric Models of Children help to reduce the telecommunications bandwidth which will be one of the more limiting factors in developing techniques for the effective practice of telerehabilitation.

4.3 Weaknesses

Admittedly, a weakness of the database is the fact that the populations, from whom the anthropometric data was gathered, were not disabled. The populations of children who participated in the original anthropometric study exhibited natural patterns of development and growth, whereas the physical development of children with disabilities is often effected by their particular disability as well as the treatment and therapy which they receive. This is an area that needs future improvement, but it does not prevent the database from being used effectively.

5. RESULTS

The developments of this project has produced 16 sets of male children models, each with a 5^{th}, 50^{th} and 95^{th} population percentile sizing. The data for the additional 16 sets of female children models has been gathered, but have not yet been added to the database. Additionally, a prototype system is still underdevelopment to automatically incorporate assessment data into the population data of the model database.

An enormous amount of work has gone into making the Anthropometric Models of Children database a reality. For a research project that was never formally proposed, the Anthropometric Models of Children have been quite successful. The models are currently being using in at least three projects outside of the duPont Hospital for Children and the VRML model database of the children takes an average of 400+ unique IP hits per week.

Additionally, the developments of this research project have been of great interested to the industry leaders in human modeling and simulation. Transom Technologies, the company that is commercially developing JACK, was so impressed by the Anthropometric Models of Children, they contacted us requesting permission to incorporate them into their Transom JACK 2.0 product release.

Further information and HANIM 1.0 compliant VRML 97 versions of the Anthropometric Models of Children can be found at: http://www.asel.udel.edu/~beitler/children

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