Digital Human Model Module and Work Process for Considering Anthropometric Diversity

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ABSTRACT

In digital human modelling (DHM), ergonomics evaluations are typically done with few human models. However, humans vary a lot in sizes and shapes. Therefore, few manikins can rarely ensure accommodation of an entire target population. Different approaches exist on how to consider anthropometric diversity. This paper reviews current DHM tools and clarify problems and opportunities when working with anthropometric diversity. The aim is to suggest functionality for a state of the art DHM module and work process for considering anthropometric diversity. The study is done by an analysis of some of the current DHM systems and by interviews of personnel at car companies about their way of working with anthropometric diversity. The study confirmed that critical production simulations are often done in early development stages with only one or a few human models. The reason for this is claimed to be time consuming processes, both at the creation of the human model but mainly when correctly positioning the model in the CAD environment. The development of a new method and work process for considering anthropometric diversity is suggested. Necessary features for such a module are that it shall be easy to use and not require expert knowledge about the consideration of anthropometric diversity. It shall also be configurable and transparent, in a sense that it should be possible to work with own anthropometric data and ergonomics evaluation standards. The module has to be flexible and have different entrances depending on the type of anthropometric problem being analyzed. An improved work method is expected to lead to faster and more correct analyses.

Keywords: Digital Human Modelling, Ergonomics, Work Process, Anthropometry

INTRODUCTION

In product and production development it is often necessary to study how a product, workplace or task will affect a potential user, both related to physical and cognitive ergonomics. Human-machine interaction has traditionally been evaluated relatively late in the development phase (Porter et al., 1993), and this has often been done by physical mock-ups which have been expensive and time demanding (Helander, 1999). To address anthropometric issues at early stages, problems are typically simplified and one or a few specific body dimensions are considered. The identified anthropometric measurement is then regularly collected from anthropometric data in a reference text or human factors handbook (Peacock and Karwowski, 1993; HFES 300 Committee, 2004; Salvendy, 2006; Jung et al., 2009). In order to reduce the need for physical tests there are benefits from using DHM simulation systems, which facilitates and improves simulations and analyses (Chaffin, 2001). A DHM tool is a computer program that uses a human model to create, modify, present and analyze human-machine interaction.

There are generally two methods to work with anthropometric diversity; a percentile based method and a custom-built method. With the percentile method a human model is created of the 1^{st}, 5^{th}, 50^{th}, 95^{th} or 99^{th} percentile according to stature and weight measurements, of a certain gender, age group and nationality, generated from anthropometric data. The custom-built method means that any desired anthropometric values are defined; omitted dimensions are calculated by regression equations. Forms of custom-built methods are the boundary manikin method (Bittner, 2000; Eynard et al., 2000; Reed and Flannagan, 2000) and the distributed method (HFES 300 Committee, 2004; Jung et al., 2008) in which body dimensions are defined for a number of cases intended to cover the target population. The problem with the percentile method is that usually very few models are tested and that it is likely that that not all users are represented in the analysis (Jimmerson, 2001; Nelson, 2001; Thompson, 2001). Creating several custom-built human models takes quite long time and quickly becomes ineffective (Jung et al., 2009).

This paper will evaluate current DHM simulation systems and clarify problems, opportunities and solutions when working with human diversity in DHM systems.

The aim is to review and suggest a state of the art DHM module and work process for considering anthropometric diversity.

METHODS

To review current DHM simulation systems, and their modules considering anthropometric diversity, a comparison of following DHM simulation systems was done: Siemens/UGS Jack 6.0, Pro Engineer Manikin and Catia V5 Human. Each system was evaluated by examining a number of criteria and by analyzing how well the system met the criteria. These criteria were defined based on existing functions, own ideas and the usability methods Cognitive Walkthrough (CW) and Predictive Human Error Analysis (PHEA):

- Choosing anthropometric data base
- Inserting own anthropometric data
- Creating percentile manikin
- Creating custom-built manikin
- Creating manikin family
- Save and load manikin data

Three qualitative interviews were conducted to get an understanding of different methods and approaches when working with anthropometric diversity in today's manufacturing industry. Six persons were in interviewed and they were all working in Swedish vehicle manufacturing industry. Their work positions varied from simulation engineers with an up to date expertise of DHM system to people with more overall responsibility for virtual manufacturing and simulation where DHM is one part. The interview questions covered topics such as previously mentioned criteria, key anthropometric variables, pros and cons as well as suggestions for improvements.

The results from benchmarking and interviews were combined with own knowledge and informal brainstorming sessions to create a model and work method for creating manikins in a DHM system. The model is presented by using the black box method where a "black box" converts certain inputs into desired outputs (Pahl and Beitz, 1996).

RESULTS

The result from the analysis of current DHM simulation systems was implemented into a matrix table that describes each criterion and how well each system meets the criteria (Table 1).

Table 1 Results from benchmarking analysis.

System	Siemens/UGS Jack 6.0	Catia V5 Human	Pro Engineer Manikin
Choosing anthropometric data base	Not possible to choose, beside the implemented data for USA (based on Ansur88).	Possible to choose between USA, Canada, France, Japan or Korea.	Depending on the library of manikins which is possible to import into the system.
Inserting own anthropometric data base	No possibility.	No possibility.	No possibility.
Creating percentile manikin	Possible to create 1st, 5th, 50th, 95th and 99th percentile for stature and weight.	Possible to continuously adjust percentile for stature.	Depending on the predefined manikins in the library.
Creating custom-built manikin	Possible to individually adjust 26 anthropometric measures.	Possible to individually adjust 103 anthropometric measures.	Manikins are pre defined in the library.
Creating manikin family	Principal component tool available in add on modules.	No possibility.	No possibility.
Save and load manikin data	Possible to save and load data for manikins.	Possible to save and load data for manikins.	All manikins are pre defined in the library.
Other	Possible to import 3D scan and SAE physical test manikins are integrated.	-	-

The interviews at the companies gave that methods and work processes are still much in a development phase, but work environment and ergonomics are something that is interesting throughout the organizations. Not meaning that DHM simulations always are given as much focus compared to other improvement methods like lean production. In a global organization the interest and understanding for ergonomics may vary a lot between production plants, and more personnel are sometimes seen as a solution to ergonomically bad planned production lines. According to the interviews, a DHM tool needs to be fast and easy to use. Using a simulation system should lead to better quality with the same work effort and the result needs to be trustworthy. An advantage of using DHM tools is the possibility to solve problems in an early phase and being able to make better decisions based on the simulations.

Today, working with DHM systems are frequently combined with qualified guessing of the final result. A simulation analysis is often done with only one or two manikins and the rest of the results are produced by imagining how the outcome would be if another person did the analysed task. There are some recurring elements which often involves poor ergonomics in assembly like engine compartment and interior ceiling. A critical area is the hands and wrists which are complicated to position correctly and this will influence analysis in a negative way. It has also been noticed that hands of the manikins are scaled proportionally to stature leading to unrealistically big hands on big manikins.

To cover all intended users the companies uses a very rough strategy involving one or two manikins based on stature percentiles. The goal can be that the biggest male (95th percentile) and the smallest female (5th percentile) should be able to do the task. Another approach is that a woman of the 50th percentile stature should be able to reach the work area. It is not unusual that even these objectives are not possible to fulfil. If that happens studies are done to expose what is possible to achieve depending on the workstation. The reason for these simplified solutions is the time-consuming processes when working with several manikins even if good features exist to assist in the positioning of a manikin. There are some alternative methods besides using a DHM system like using anthropometric data directly from tables or video analyses. A feature that the interviewed subjects would like to see in DHM simulation systems is the possibility to rapidly scale a manikin in order to see how a work position will affect a person with other body dimensions.

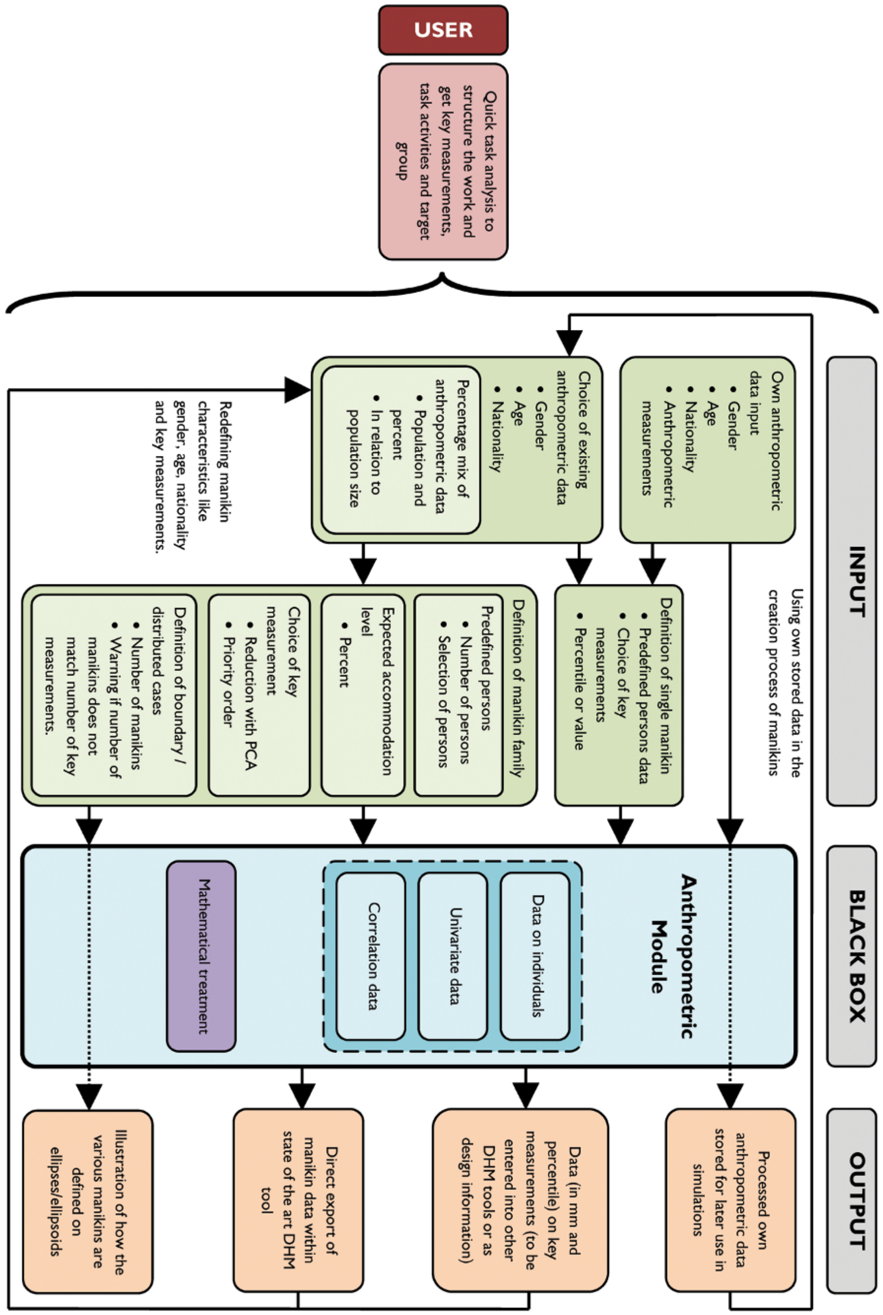

FIGURE 1 Flowchart depicting the module and work process.

DISCUSSION

Current DHM simulation systems are advanced, but many functions are not fully utilized because of time constraints in today's work. This can be compared to the fact that there are several clear requests not met by today's DHM system. The results from this study can be used when developing a new DHM simulation system or improving an existing system. The resulting work method will most likely evolve and transform during such a development.

Such a method and module needs to make it easy when working with anthropometric diversity. The module should have an easy to use graphical user interface similar to the web-based generation system created by Jung et al. (2009). It should be possible to create single manikins as well as manikin families. Possibilities to implement own anthropometric data would lead to a better connection between the simulation and the physical work station and its users. The module must be transparent, meaning that it should be easy to import and export data of anthropometric measurements and body angles. This would make it possible to communicate with manikins in other DHM simulation systems with minor modifications. The module combined with a work process inspired by Hanson et al. (2006) is illustrated in Figure 1. The process starts with the user doing task analysis. Depending on the situation it is possible to add own anthropometric data or choose data from within the system. Next step is to define single manikin or a manikin family. The choices and data are processed in the anthropometric module and depending on previous choices the result can either be inserted into a existing DHM tool or within a new DHM system in which the module are integrated.

The coming steps in the development of such a module will add focus on related areas like anthropometric measurements, correlation data, statistics and biomechanics. To be able to fully use functions like manikin families in a proper way there is a need for the DHM simulation systems to evolve and be more automatic and supportive for the tool user. Such a system should calculate a possible human motion from one position to another and repeat the simulation for a number of manikins with different body dimensions. Focus would be more on covering the target population with several manikins and finding key measurements than on visual simulations and guessing.

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