Use of digital human modelling and consideration of anthropometric diversity in Swedish industry

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This paper study and clarify problems, needs and opportunities when working with anthropometric diversity in digital human modelling (DHM) systems. A comparison between product development and production development in Swedish automotive industry is made. Interviews with DHM users and ergonomics specialists about their way of working with anthropometric diversity confirmed that simulations are often done 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.

1. Introduction

An important process of the product or production development is to study how a product, workplace or task will affect a potential user. These human-machine interaction studies have been done relatively late in the development phase (Porter et al., 1993), with expensive and time demanding physical mock ups (Helander, 1999). In order to reduce the need for physical tests in modern research and development, digital human modelling (DHM) simulation software are used which provide and facilitates rapid simulations and analyses (Chaffin, 2001). The DHM tool uses a digital human model to create, modify, present and analyze human-machine interaction. By using DHM simulation systems it is possible to have a proactive and efficient consideration of ergonomics during the development process.

When creating a digital human model in a DHM tool, there are generally two methods available; a percentile based method and custom-built methods. The percentile method offers a number of predefined percentiles (1^{st}, 5^{th}, 50^{th}, 95^{th} and 99^{th}) according to stature and weight measurements of a certain gender, age group and nationality. A human model is then generated from anthropometric data and based on the previous choices. The custom-built methods mean 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; Reed and Flannagan, 2000; Speyer, 1996) and the distributed method (HFES 300 Committee, 2004; Jung et al., 2008) in which body dimensions are defined for a number of cases (human models with specific anthropometrics) intended to cover the target population. The problem with the percentile method is that usually very few models are tested and it is likely that not all relevant bodily configurations of targeted users are represented in the analysis (Jimmerson, 2001; Nelson, 2001; Thompson, 2001; Högberg, 2009). Creating several custom-built human models requires more time and may quickly become ineffective (Jung et al., 2009). The latter problem can however be reduced by using automatic generation of representative human models and by using automated simulation processes.

This paper studies the use of DHM simulation systems in the Swedish automotive industry and clarifies problems, opportunities and solutions when working with human diversity in DHM systems. Another objective is to compare the use of DHM systems in product development with the use in production development.

2. Methods

Nine semi-structured interviews were conducted to get an understanding of different methods and approaches when working with anthropometric diversity in today's automotive industry in Sweden. In total sixteen persons were interviewed. Their work positions varied from machine operators to simulation engineers with an up to date expertise of DHM system and also people with more overall responsibility for virtual manufacturing and simulation. The interview questions covered topics such as the use of DHM tools, anthropometric databases and creation of manikins, key anthropometric variables, pros and cons of current DHM tools as well as suggestions for improvements. The interviews were audio recorded and notes were taken.

The result from the interviews was analyzed and needs and problems of today's DHM use were identified. In addition, a comparison between product development and production development was done.

Table 1. Compilation of interview results presenting the use of DHM simulation system in Swedish automotive industry

	Production development	Product development	Total
Active use of DHM tools	2/5	4/4	6/9
Representative database in the DHM tool	1/2	2/4	3/6
Use of percentile manikins only	2/2	2/4	4/6
Use of boundary case manikins	0/2	2/4	2/6
Use of distributed case manikins	0/2	0/4	0/6
Manikins based on user or customer	0/2	1/4	1/6
Measurement for target group of interest	0/5	3/4	3/9

3. Results

The use of DHM simulation systems varied a lot, both between different companies but also within the companies when comparing product development departments to production development departments. A common case was that the product development departments had come further in their work with DHM systems, particularly in respect to consideration of anthropometric diversity. Often the production development departments had recently started to work with DHM systems or was about to do so soon. A compilation of the interview results and comparison can be seen in Table 1.

Overall, most analyses done with DHM tools are of situations where reach and clearance can be a problem. Interviews showed that used methods and work process generally was in a development phase and not fully evolved. Several companies did not use DHM tools; instead they used anthropometric data directly from tables or analyzed ergonomic problems with video recordings. The video analyses were done with one person randomly selected from the work personnel or at best two persons; one long and one short person. According to the interviews, a DHM tool needs to be fast and easy to use. It should be possible to rapidly scale a manikin in order to see how a work position will affect a person with other body dimensions. A wanted function is the possibility to rescale a population to better fit the target group. Using a simulation system should lead to better quality with the same work effort and the results need to be trustworthy. The interviewed persons believe that using DHM tools give the opportunity to work with “active” development where it is possible to redefine a product or workplace based on simulation results. The possibility to early evaluate solutions without creating a physical mock-up reduces costs and development time.

The analyses done in the DHM systems are currently often combined with guesswork based on simulation results and self-knowledge to produce result for the rest of the population. This fact is due to the slow and difficult process when manually position the manikins. To cover all intended users a large part of the departments use 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 and 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.

In contrast to this rough strategy with few manikins, there were also some departments that used a more refined approach on the problem and used manikin families. These manikin families were based on Speyer (1996), which contains twelve human models supposed to cover the target population. The Speyer family is based on three key measurements: stature, waist circumference and sitting height. Another solution was to define the population and target groups in the beginning of project and based on that data five stature and weight percentile manikins were created to cover the extremes of that population. These five manikins are then used during the whole project time.

Most of the interviewed departments used anthropometric data that was not included in the DHM systems. To compromise the fact that it is difficult and time-consuming to fully implement anthropometric data into the DHM systems percentile measurement for stature and weight of own anthropometric data is used and other measurements are calculated by the software’s regression model. Some had not considered the choice of database and did not know

what database that was used and did not have a plan for how to choose anthropometric resources.

Most departments did not have any possibilities to verify their simulated results with physical testing, mostly because they did not have any data for individuals in their target group. Three of the interviewed departments had taken measurements on individuals in the target group of interest. All these departments worked with product development and one of these departments had also implemented a method in where they first did analyses with manikins of the same size as earlier measured company personnel. This method made it possible to verify the analysis with results in a physical clinic where the personnel did the analyzed task.

4. Discussion

The use of DHM simulation systems varies a lot when comparing product development and production development where product development generally has developed methods and work processes for the consideration of anthropometric diversity. This can have several reasons; the product and production have different customers and focus is put on the product development customer who is the final user of the product. In production development, DHM work in general are not always given as much focus as other improvement methods like lean production which is easier to connect with income and expenses. At the production development stage the product is already created and changes to the product at that stage often involve much work which leads to high costs.

There is an evident need for better communication between production development and product development, foremost feedback from production development to product development but also a discussion between ergonomics departments to exchange knowledge and share problems. It would also be helpful with a good communication between DHM users and company physiotherapist which usually does not have any knowledge of DHM systems. The DHM simulation systems need to be more easy to use, more automatic and supportive for the tool user. It should be easy to almost automatically generate a possible human motion from one position to another and repeat the simulation for a number of manikins with different body dimensions. There is also a need to easily implement own anthropometric data and scale existing databases to better fit the target population. This would lead to more focus on covering the target population with several manikins and finding key measurements than on visual simulations and guessing.

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