Using Digital Human Models

When designing a product, the aim is to design a product that the users like to use. It should do what it is supposed to do, please the senses and the dimensions of the product should fit the body dimensions of the user.

To dimension a product, the designer needs to analyze what product dimensions are important and what relation there is between the human dimensions and these product dimensions. There is a lot of information available about human dimensions, presented in various ways, from tables to 3D digital human models. Thus, based on the analysis, a choice needs to be made from the available information. The focus of this reader will be on the use of 3D digital human models (DHM) in the dimensioning part of the design process.

As a designer you will not develop your own DHM, but use an available model.
Whenever you use information collected by others, it is important to question whether this information is reliable and whether it could be used for the specific design problem you are working on. So, when using a DHM, you will need sufficient background information about the DHM to answer these questions.

This background information is needed to get insight into the assumptions that have been made in the process of developing the DHM. For this is the main challenge for the product designer: not only trying to get insight into the assumptions made during the process of using a DHM to decide upon the fit between product and user, but taking the assumptions ‘hidden’ in the DHM into account as well. Only with a sufficient insight into these assumptions it is possible to predict how well the product will fit its users.

Analysis

To design a user friendly product, you need to know more about who this user is as well as about how the user is expected to handle the product.

Who is the user?
One needs to describe the user as detailed as possible: how old is the user, what gender, what ethnic background, etc. Apart from this general information it is important to know whether the user might have limitations that could influence the use of the product. This information enables you to look for specific information about the user of the product.

User-product interaction
To decide upon what information about the product user you need, it is important to know what the user does or is expected to do with the product and within what context the product will be used. The focus of this reader is on the product-dimensioning part of the design process. The designer needs to analyze what product dimensions are important and what relation there is between the human dimensions and these product dimensions. When redesigning an existing product one could get information about the user-product interaction through observational research. When designing a new product this information could be obtained by observing the use of similar products or tests with models or mock-ups.
Knowing what dimensions are important and how human and product dimensions are related is only half of the information needed. It is as important to know what requirements there are for comfortable use of the product. Literature should be researched or tests should be done to find within what boundaries use of the product is possible and comfortable.

Phase of the design process
The phase of the design process determines what kind of information you need. When you set up a program of requirements for the dimensioning of a product, you have expectations about what users might do. But, because you do not know yet what the product will look like, you can only give the outlines of the dimensions needed. Whereas when you are assessing the dimensions of concepts or existing products you can look into more detail how well the product fits the (future) users.

Anthropometric data

There is a lot of information available about human dimensions, presented in various ways, from tables to 3D digital human models. Thus, based on the analysis, a choice needs to be made from the available information.

Anthropometry
Up till the Industrial Revolution products were made on demand for individuals. So the dimensions of the product could be tailored to the needs of the user. The Industrial Revolution made it possible to produce products in large quantities. Information about the dimensions of groups of people was therefore needed.
One of the founding fathers of the science of measuring the dimensions of groups of people (anthropometry) was the Belgian scientist Adolphe Quetelet.
Anthropometry could be static (measuring non moving body parts) as well as dynamic (measuring body parts during movements of the body).

Who are measured
The first group of people measured on a large scale, were soldiers. The next group measured were factory workers: with the implementation of assembly lines and the wish to speed up the production process, data about their body dimensions was part of the information needed.
Dimensions of babies and children have been collected by the Health Department for many decades to get insight into normal growth and development of children.
Nowadays body dimensions of various groups of people have been measured: from Dutch elderly people to Chinese head dimensions.

What is measured
The most popular body dimensions to be measured are stature and weight.
In large scale measuring projects many other (static) body dimensions have been measured, not only the length of the various parts of the body but also the shape of the body parts.
Apart from the body dimensions the ranges of motion of the joints are measured.
Growth and the changes in body dimensions of groups over a period of time have been studied as well.

Methods
Main methods of measuring are:
Questionnaire
Questionnaires are used to ask for information about stature and weight. In filling in the questionnaire people tend to give socially acceptable answers: the value of the dimension they fill in tends to shift to the socially accepted mean value.
Tools
The easiest available and most used tools are scales, rulers, compasses and measuring tape.
Digital stereo photogrammetry
This method uses several photo camera's that take a picture of (parts of) the body. These pictures are digitally combined into a 3D body image.
Laser scanning
A laser beam is used to scan the body to produce a 3D digital image.

Presentation of data

There are several ways to present the collected data.

Main presentation forms are:

Tables and templates

Widespread and most used way to present anthropometric data. Tables usually present the mean value of the dimension together with standard deviation, so the value for any percentile could be calculated. Templates show a human figure in front or side view in one or more functional anatomical postures. Examples of this kind of models are the scales by Dreyfuss, the Bosch template and Kieler Puppe.

2-dimensional

Programs like Ellips present two body dimensions and their correlation.

3-dimensional

There are two ways to present 3D information: as physical models (think of crash test dummies) and as 3D digital human models (like ADAPS or the SolidWorks model).

Digital Human Models

Whenever you use information collected by others, it is important to question whether this information is reliable and whether it could be used for the specific design problem you are working on. So, when using a DHM, you will need sufficient background information about the DHM to answer these questions.

History

The development of DHMs keeps pace with the digital revolution. As soon as the computer facilities made it possible, the first DHMs were developed, ADAPS being one of them.
ADAPS started as a graduating project in the late 70's of the 20th century. When the first PCs started to enter the Faculty of IDE (in 1990), ADAPS was converted to a version that worked on a PC; a version that looked similar to the ADAPS still in use nowadays.
The DHMs were based on the data that were available at that time, data based on measurements taken with the traditional measurement equipment. Most of the first DHMs used data collected by Dempster from American soldiers. As soon as data from other populations became available, this was implemented in the DHMs. For example the ADAPS 'family' now consists of the original American pilot, Dutch male and female adults, Dutch male and female elderly and Dutch children (0-4 years of age).
The DHMs based upon traditionally measured data all have more or less the same structure. They consist of a skeleton (links) and a surface, connected to these links. Most of the models scale proportionally to stature: when the model gets taller or smaller, the other dimensions get proportionally bigger or smaller.
With the development of new measuring methods (digital photogrammetry and laser scanning) new DHMs started to arise. These models are based upon a large amount of scanned body surface points so they can be very detailed. Advantage of these models is that they give detailed information about the shape of the body(parts).

Selecting a DHM

When you decided in what phase of the design you want to perform the simulation and who are the users of the product (gender, age, ethnic background), the next step is to select a DHM that could be used for the simulation.
To select the right model, one needs sufficient information about the DHM:

- what population has been measured (does this match the user population)
- what body dimensions have been measured (did they measure the body dimensions relevant for the user interaction that you are looking at)
- how were these dimensions measured (have the dimensions that play a role in the user product interaction been measured accurately enough)
- when were the measurements taken (when this has been decades ago, one needs to reckon with secularization)

Adapting a DHM

You try to select a DHM that matches the user population as closely as possible. When you do not succeed in finding a match (for example when the available DHM is based upon data from the Dutch population and you are designing for the Italian market) and you still want to use the DHM, you need to adapt the DHM.

To do so, you could take the following steps:

- try to find information about the body dimensions of the product users (if you cannot find any information, you have to take measurements yourself)
- change the stature of the DHM to the average stature of the user population
- compare the dimensions of the DHM and of the user population (focus upon the body dimensions that are relevant in the user product interaction)
- estimate the differences between the DHM and user population for the relevant body dimensions
- repeat this process for a small and a large user

Through knowing the extent of the differences between DHM and user population it is possible to estimate the accuracy of the DHM for this design problem.

The procedure as described may also work for special user groups. As an example: when designing a hand bike for handicapped Indian children, it is still possible to use the ADAPS DHM (that provides models of Dutch children). In this case you follow the described procedure, but focus upon the length of the upper body and arms only. Through adapting the dimensions of upper body and arms of the DHM to the values you measured of these dimensions of the Indian children, you are able to use the DHM to determine the size of the bike.

Functional postures

DHM's usually present information about measurements taken in static, so called standard anthropometric postures only. But you want to use a DHM to predict how well the product fits the user when using the product. So you need to know how well the DHM matches the user not only in these standard anthropometric postures, but also in so called functional postures. To estimate this, you can follow the procedure as described for adapting the DHM, but now compare measurements taken from users in postures you expect them to adapt when using the product with the DHM in similar postures.

Using a Digital Human Model

The DHM is used to assess which part of the users will (or will not) be able to use the product and which part can use the product comfortably.

When determining the requirements for the dimensions of a new product the procedure is as follows:

- have the DHM adapt one of the postures you want to assess (a posture you expect to be needed to use the product)
- scale the model till it has the length of the smallest person who should be able to use the product comfortably
- determine the lowest value for the product dimension in question
- scale the model till it has the length of the largest person who should be able to use the product comfortably
- determine the highest value for the product dimension in question
- repeat this procedure for all relevant postures

The procedure to evaluate chosen dimensions or the dimensions of an existing product is:

- have the DHM adapt one of the postures you want to assess
- scale the model till you find the smallest person who is just able to use the product comfortably
- scale the model till you find the largest person who is just able to use the product comfortably

- if relevant: follow the same procedure to find the smallest and largest person for whom product use is no longer possible
- repeat this procedure for all relevant postures

One of the most difficult parts of the simulation is the translation of human postures into model postures. Be aware of the influence of the designer on this process: the designer is the one who determines the postures the user is expected to assume and the designer also assesses whether the postures of the DHM match these users' postures.

Evaluation

For this is the main challenge for the product designer: not only trying to get insight into the assumptions made during the process of using a DHM to decide upon the fit between product and human dimensions, but taking the assumptions 'hidden' in the DHM into account as well.
Only with a sufficient insight into the assumptions it is possible to predict how well the product will fit its users.

Assumptions
Result of the use of a DHM is either a program of requirements for the dimensions of a product, or a prediction about how well the dimensions of a concept or existing product are adapted to the intended users. However well you prepared and executed the simulation, it is always necessary to look back at all aspects of the process to be able to assess the accuracy of your predictions.
In the process of using a DHM there are two categories of assumptions: 'model' assumptions and 'designer' assumptions.

'model' assumptions
In the process of construction of a DHM, a number of assumptions will have been made.
As the user of a DHM you should check whether the DHM provides information about the following:

- which population has been measured to obtain the data for the DHM
- have these measurements been taken of a representative sample of this population
- which dimensions have been measured of this population
- when have the measurements been taken

When you look at a DHM you see a transformation of original data (derived from a human population), using mathematical and computer graphics algorithms. To be valid, the model's geometry should possess (as close as possible) a one to one mapping with the original human population that has been measured. Values for missing or non-existent anthropometric variables need to be estimated to construct a complete DHM.
As a DHM integrates 1D information (lengths, widths etc.) into 3D-information (space requirements), the DHM can be validated for the 1D information only.
Unfortunately, information about the validity is rare and usually not available with the DHM.

'designer' assumptions
The relationship between standard anthropometric postures (the postures in which the population has been measured) and functional postures (the postures which the users of the product will assume) is the area of transition from 'model' assumptions to 'designer' assumptions. On the one hand the DHM-builder will check some of these postures (as there is an infinite number of postures, checking all postures is impossible), on the other hand the designer will decide about what postures are relevant and will put the DHM in this posture.
Depending on experience with the DHM the ability of the designer to match the DHM postures to real life postures may vary. Thus may the outcome of the predictions.

Whereas it is rather easy to distinguish between possible/impossible use, the area of comfort/discomfort depends on criteria the designer decides upon. Thus the experience of the designer will influence these decisions as well.