Enhancing the use of anthropometric data

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Abstract

Anthropometric knowledge is most frequently used by designers and product evaluators in the form one-dimensional data to verify whether the product dimension is fitting the human dimension. Several ways of how anthropometric data are used can be distinguished in this matter:
- Ego-design: your own body dimension as a guide;
- Average-design: body dimensions of the average as a guide;
- Design for P5: body dimensions of the smallest person as a guide;
- Design for P95: body dimensions of the largest person as a guide;
- Design for P5-P95; body dimensions of the smallest and largest person as a guide. This type is used most commonly and means that excluding 10% is acceptable.
- Design for all: implies the continuous effort during the design process to exclude as few persons as possible

To make this anthropometric world easier to understand two tools are discussed. The tool 'Ellipse' will demonstrate how easy it is to analyse a fit-problem with multiple 2D views. The tool 'Persona' will visualise the geometrical problems in the human-product-interaction with living persons or with digital models.

Introduction

Many ergonomists are not aware that the anthropometry they use is mostly 1D. This does not mean it is of less value, but in this paper will explain why it is important to realise this and how it can be extended to 2D and 3D or even maybe 4D information, which might be more appropriate for daily use in a design or evaluators environment.
Let us first consider the eight design types around us, of which the most are earlier described in Dutch in Molenbroek (1994) and in Dirken (1997-2004).

1 *Design as Procrustus*

This means as in the former Greek Mythology that the user is fitted to the product

2 *Design for Ego*

This means the designer only looks to his own size and assumes his designs will fit everyone else.

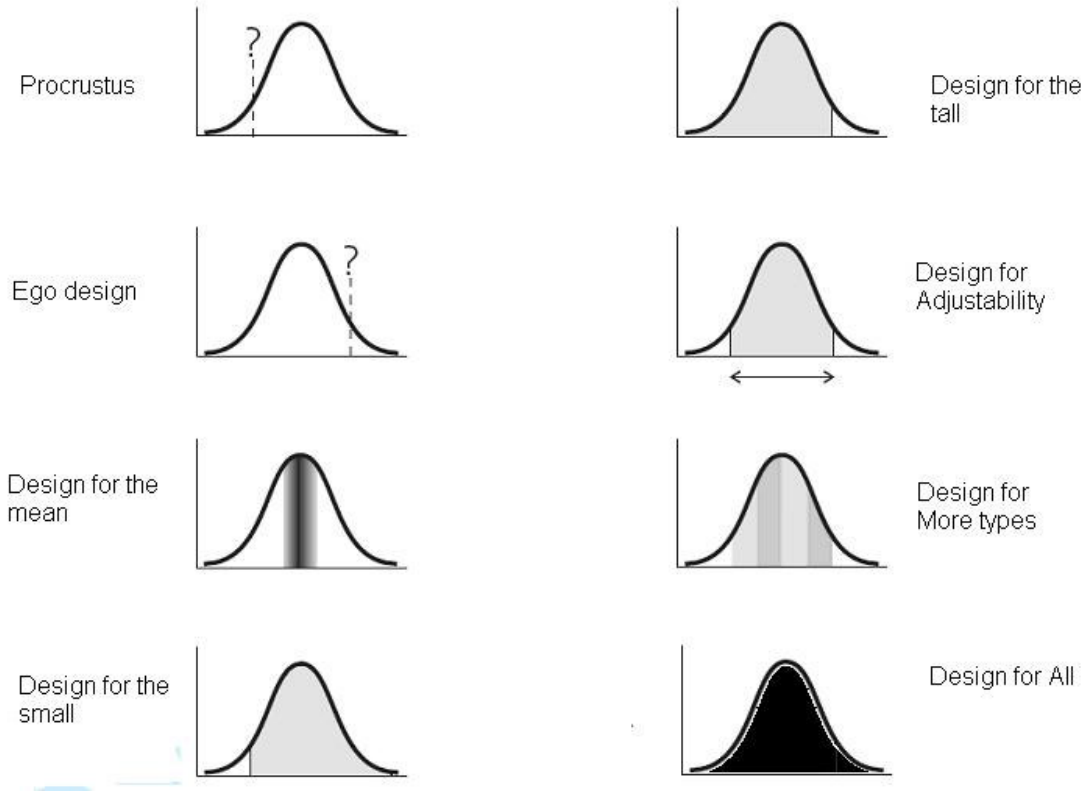

Figure 1: Overview of Anthropometric Design Types.
Axis description: y= frequency and x= percentile 1 to 100.

3 Design for the Mean

The designer has thought about the variation in sizes and decides to take the average to comfort all and to minimize the discomfort of the tall and the small. Mostly everybody outside the mean is excluded.

4 Design for the Small

The designer is aware that when using the mean values the small people will have problems, so he takes care of that everything fits at least the weak and the small ones. For a nutcracker for example it means that the small and the weak can crack the hardest nut, but that the strongest person will probably crack the nut cracker.

5 Design for the Tall

The designer is himself very tall and has experiences that he bumps his head to all kinds of design and is strongly motivated to fit at least the tall and strong users and might forget the small and the weak.

6 Design for more types

When a product has several types to fit the variation of users, like in shoes, clothing or personal equipment the most simple system consists of small, medium and large and currently more and more is found an extra large(XL) or even extra extra large(XXL) size, because of the increasing overweight in the society.

The anthropometric analysis of the data underlying the decisions of which part of the population should fit on which type of the product is less described. Exceptions are Roebuck (1997) and HFES (2004) Later in this paper it will be shown that the tool ELLIPSE is meant to contribute in this field.

7 Design for adjustability

When using office chairs it was a great improvement in comfort when in the seventies the sitting heights and later the arm rests and seat depths and some other parts sometimes became adjustable within a few seconds. The disadvantages of this type of solution are how to determine what the limits are and to provide that the user will not forget to adjust to his/her size.

8 Design for All

This does not mean you have to design for all 6 billion people on the earth but it means to consider during the whole design process to exclude as less as possible. Design for All is also known as Inclusive Design or described as design for the widest possible audience (Include, 2005)

To understand which steps are important figure 2 shows the anthropometric design process, consisting of a series of sequential and parallel sub processes.

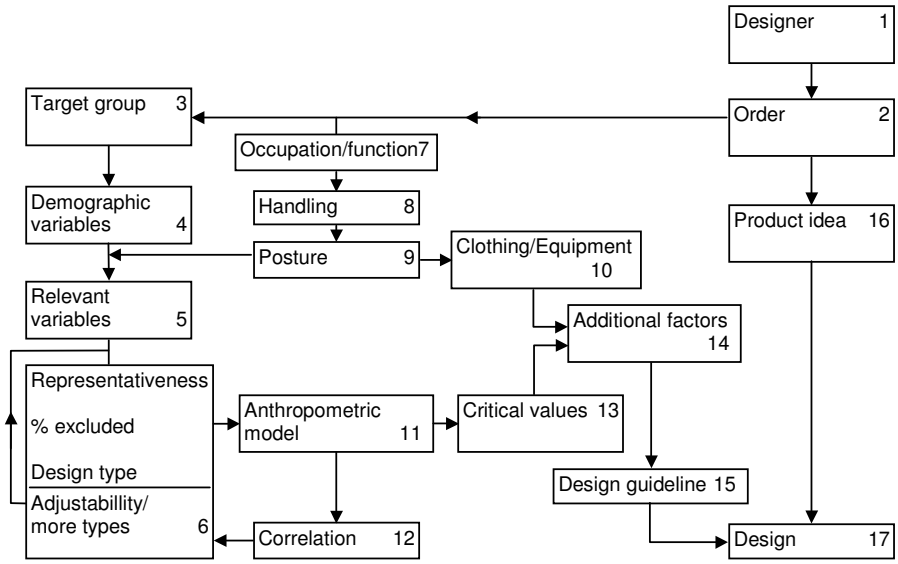

Figure 2 The Anthropometric Design Process [Molenbroek, 1993]

According to this model the facts about the following elements should be known:
Box 1: a designer accepts a assignment to analyse and redesign schoolfurniture
Box 2: The object of the study (i.e. chair & table)
Box 3: The target population (i.e. European children)
Box 4: The demographic variables (i.e.4-20 years of age, students)
Box 5: Relevant anthropometric variables (see table 1); a key dimension is the popliteal height and not the stature as was assumed in the past (Molenbroek,2003)
Box 6: The criteria for anthropometric data.

- Relevance of dimensions (see box 5)
- Representative of population: the population for which is designed should also give the anthropometric data.
- Precision: statistical considerations have to be applied in the accuracy of sample results.
- Design type: See figure 1.
- Adjustability: to fit a product to a range of users in various dimensions at least three solutions are possible:
  - adapt the product to a specific user
  - make the product adjustable
  - create different sizes of the same product. For school furniture this is the most used solution, it is a compromise between costs and anthropometric fit.

Box 7: The function of the user (i.e. a student sitting in a classroom)
Box 8,9,10 and 14: These factors result from clothing, posture etc. and also from the extra space the designer allows the user.
Box 11: Depending on the facilities of the designer an anthropometric model will be available as a table, or as a 2D or 3D model.

Box 12: Correlation between the relevant variables should be taken care of to avoid exclusion of part of the user-population; the tool Ellipse takes care of this.
Box 13: With knowledge of correlation coefficients and scatter diagrams about body dimensions of the target population the design and evaluation of a chair can be improved.
Box 15: Guidelines for the specific dimensions of each set (chair + table) are defined in this stage of the design process and, in the present study, will result in a proposal for a new European standard.

Another important aspect is the understanding that the product dimensions differ mostly from the users-dimensions. Table 1 shows the relation between the dimension of the user and the product. The ergonomists has the task to determine what the content of the terms in figure 1 and 2 and table 1 are.

P1	P99	User	additional	Product
429	583	Buttock-popliteal depth	-5 cm	Seat depth
344	516	Popliteal height	+ heel height	Seat height
316	454	Hip breadth	+ clothing +comfort	Seat width
177	299	Elbow-rest height		Armrest height
362	570	Bi-acromial breadth		Width backrest
798	1015	Sitting height		Height head support
457	651	Acromial height		Height back support

Table 1: The concept of product dimensions versus users dimensions. Dimensions in mm. Results are from the elderly in the GDVV-project (Molenbroek, 1987)

Until now this paper described 1D-anthropometry, in which there were no relations between the dimensions assumed. The authors of this paper assume that more then 50% of the anthropometric applications are (unfortunately) just used as 1D-application. This can become less in future when proper education tools are developed to show the designers that 1D-applications only show one window of the 3D real world. Useful free sources for 1D, 2D and 3D-anthropometry are listed on the website of WEAR (Wear, 2000). The following paragraph is meant to elaborate more about 2D and 3D

Ellipse
To study the relation between two or more body dimensions basic statistical software can be used but needs an investment money and time, which is often not done by designers and product evaluators. Therefore a simple interactive tool called Ellipse was developed, based on bivariate normal distribution algorithms from Sokal and Rohlf (1981), which draws the relation between two variables on a simple way (Molenbroek, 1994 and Molenbroek et al., 2003). Ellipse allows you to display two-dimensional sample data as points in a scatter plot and find out what percentage of the sample data are within a window that is drawn by the user for example to see which limits of the size of a certain size mark product, will result is which percentage of the population.

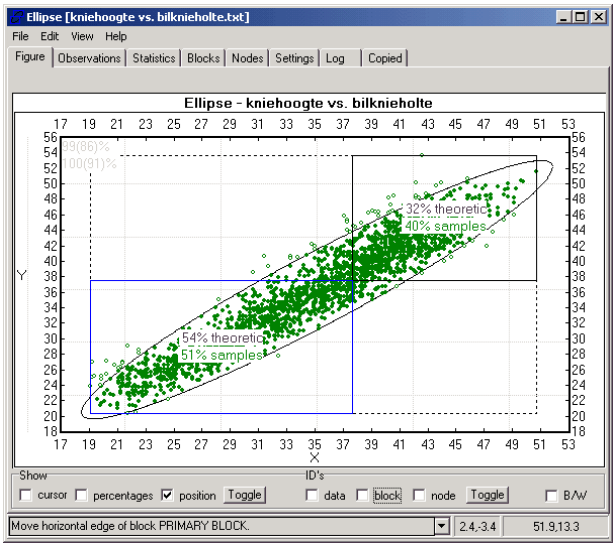

Figure 3: Example of working with the tool Ellipse, which makes it possible to shift rectangles with including % of the sample over a bivariate distribution. Axis description: x=popliteal height of Dutch children age 2-12 years, y= buttock-popliteal length of the same Kima-sample (n=2400)

Input data for Ellipse are two columns of anthropometric data or the summative alternative: two mean values, two standard deviations and a correlation coefficient that shows the relation between the two variables.
More information about Ellipse can be found on www.dined.nl/ellipse.

Persona
This is a yet non-existing tool that is useful in the authors view to work effective with 2D or 3D-digital human models (DHM) or with test persons.
What should Persona do?
It should have an overview of information of the widest selection of anthropometric tools in the world and it would assist in helping to select which tool would be the best to do the job in the given context. New developments in DHM should be easy to add. Experiences of the authors with DHM resulted earlier into overviews and criteria for selection of a proper DHM (Lombaers, Molenbroek and Osinga, 1986; and Molenbroek, 1994).
Criteria that should be build in Persona and that could be used to ask users questions step by step to be able to give a proper recommendation to the user (Table 2), which also depend on the phase in the design process (Figure 4).

CRITERIUM	DESCRIPTION
1 Knowledge	Having basic knowledge like what is in the introduction of this paper about 1 D, 2 D and 3D data and their place in the design process and about the concept of user dimension distinguished from product dimensions
2 Means	The necessary means in hard, soft- and orgware, like type of computer and operating system and which design software is used. For example SAFEWORK works fine with CATIA on a workstation but is on a pc only very recent available and should now work with for example a Solid Works trough an Digital Mockup Unit.
3 Interpretation.	If two or three people see a different meaning in how the DHM should be explained, then that DHM is not usable
4 Flexibility	If the DHM is easy to modify in posture and perhaps also in the design then it could be called flexible.

5 Investment in time	If a DHM cost only a short time to learn and is intuitive in itself or it takes a heavy course of 1 or more weeks, that make a lot of difference for a designer or researcher.
6 Investments in money	What are the costs to purchase the system and what are the costs per design
7 Reality	Which populations are inside the model and which products or workplaces can be simulated. How old are the data? And is it clear where the data comes from? Can own data easy be added. Which aspects are simulated and how many dimensions? 2D or 3D? Does it take care of secular growth? What detail is simulated?

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Table 2: Criteria that should be discussed when in the process of achieving or using a Digital Human Model.

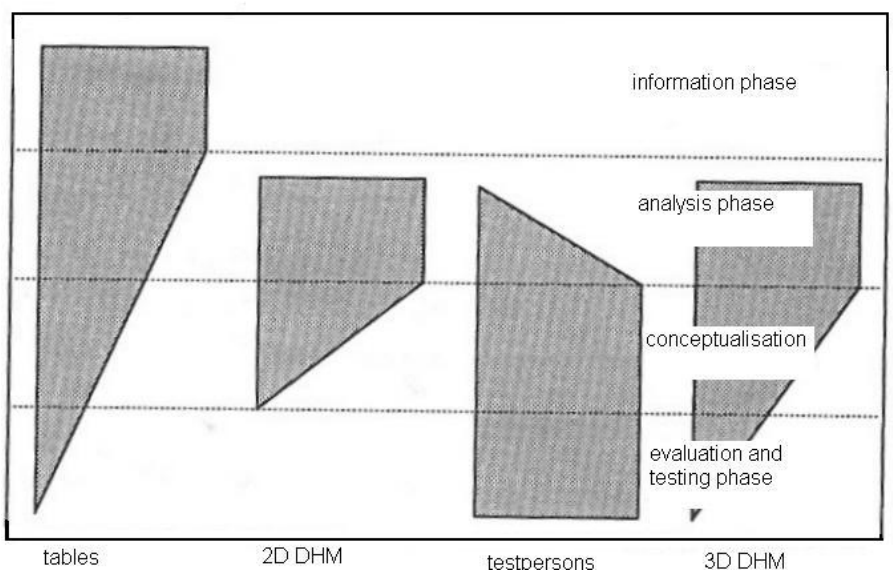

Figure 4. The usage of a (digital) human model is not only depending on it features and on the cooperation within the design but also on the phase in the design process. Axis description: x= types of anthropometric models; -y= influence of model within the phase of the design process

For example are the hands simple blocks or is every finger consisting of 3 digits. Is there a detection collision with own body parts or with other parts of the design? Can it take video data or 3D-data as input?

Persona: Visualisations in DHM
Further it should have a database with short videos of usage situations with real people like the system called HADRIAN build by Mark Porter in Loughborough. But not only from several disabled people like Porter had done, but also from the normal variety in small, large, fat and thin people, from young and old, male and female and from several cultures. In the Muybridge-simulations (Muybridge on the web) a variety of usage of products in age, gender and product type, can be seen.

Persona: Testing with Mock-ups
If the design is further developed and is prototyped testing with DHM should be replaced by testing with real life test-persons. These tests, but also or other tests with pre-processed and not-yet-ready-to-produce product images in 2D or 3D (like in foam or wood) are extremely useful and save costs later in the production process. Tools like Persona will give a step for step advice about how to select test-persons

and how to instruct test-persons when they are going to enter a test. The reason for this tool is the experiences the authors of this paper have in a European research and development project (called Friendly Rest Room, FRR (2005)), that there are so many ways for misunderstanding during these tests.

Wear

It might be that the WEAR-project in the near future will answer this need to tools like Persona and Ellipse in her current project.

WEAR is an international collaborative effort to create a world wide resource of anthropometric data for a wide variety of engineering applications. The Wear-group was started at San Diego at the IEA-HFES conference (Wear, 2000). The following countries/institutions are currently participants:

COUNTRY	INSTITUTION/COMPANY	CITY
Australia	Sharpdummies	Adelaide
Brazil	National Institute of Technology	
South Africa	Ergotech	Pretoria
Japan	Digital Human Laboratory	
Taiwan	National Tsing Hua University	
Canada	National Research Council	
USA	Wright Patterson Air Force Base, CARD-lab	Dayton
USA	National Institute of Technology	
USA	National Institute of Technology	Washington
France	Laboratoire Anthropologie Appliquée, Université René Descartes	Paris
Netherlands	TNO Human Factors Soesterberg	Soesterberg
Netherlands	Delft University of Technology, Industrial Design Engineering	Delft

Table 3: Overview of participants in the Wear-group

Conclusion

Although the digital world helps to solve anthropometric problems in such a way that data are more easily accessible and can be used to improve the current Digital Human Modelling. Still this improvement is urgent necessary, because misunderstandings about anthropometry are growing in number and size with the growing amount of 1D, 2D and 3D-data; i.e. discussions about automatic landmarking in the 3D-scanning process is for the majority of the scientists still experimental and only applicable on hard bony points, but on the other hand it is used in large scale research projects.

Another misunderstanding is that it is easy to get the data in an understandable way to the users: if these users (many of them are small industries and design companies) are only used to 1D-data and only the one that are related to there own products and on there own way of using it, then 2D and 3 D-data are images of a complete other world that needs translations and education. A shoe-designer will most probably not understand how to cope with reach envelopes. Further there are almost neither no anthropometric tools nor good quality 3D-data available for Small and Medium Sized Companies. At last tools like Ellipse and Persona can help to use anthropometric data without a large investment in time and money to solve a size problem.

Ellipse is available but Persona needs to be developed in the near future.

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Muybridge on the web: http://web.inter.nl.net/users/anima/chronoph/wrp/index.htm

Wear 2000; http://ovrt.nist.gov/projects/wear/