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How can we ‘design for all’ if we do not know who is designed out and why?

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Abstract. This paper describes our novel approach to supporting the ‘design for all’ philosophy of design. Our approach has been to create a database of individual people, in terms of their 3D anthropometry and functional abilities. Datasets for individuals are kept intact, a radical departure from the traditional approach which involves effectively ‘dismembering’ people to create tables of percentiles for every dimension of interest. This database is accessed by HADRIAN, our CAD based design tool, so that proposed designs of products or services can be automatically evaluated for each individual, based upon criteria set by the designer (e.g. access, reach, vision, mobility and strength). The tool can identify which individuals will be ‘designed out’ and can support the designer in modifying the proposed design to achieve a greater percentage of people accommodated.

INTRODUCTION

Attempting to ‘design for all’, including people who are older or have disabilities, exposes a number of limitations of current anthropometric and biomechanics databases. We aim to address these limitations in our current research project entitled ‘A design tool for the multivariate estimation of percentage accommodated’. This research is funded by the UK Engineering and Physical Sciences Research Council (EPSRC) through its EQUAL Initiative (Extending Quality Life).

Ashworth et al (1994) give some indication of the extent to which people who are older or disabled experience being ‘designed-out’. They report that 21% of US 65-74 year olds, and 55% of those over the age of 85 years, had at least some difficulty with home management activities, including activities of daily living (ADLs) that are necessary for personal independence in the community. Avlund & Schultz-Larsen (1991) found that no one in their sample of 70 year-olds could perform such activities without help.

We believe that there is a need for a new approach in order to effectively support designers when attempting to ‘design for all’, be it in the workplace, at home or in public areas. The novel features of our approach will be summarised in this paper. Two further papers will be presented at this conference, describing the creation of both a computer database of individuals (Oliver et al, 2002) and our new software tool HADRIAN (Marshall et al, 2002) which extends the functionality of the SAMMIE CAD system (Porter et al, 1999).

The main limitations of current anthropometric and biomechanics databases include their mode and format of presentation, their lack of support for investigating multivariate issues and the lack of holistic information including specific task and environmental factors.

MODE OF INFORMATION PRESENTATION AND FORMAT ARE CRITICAL

From a telephone survey of 50 UK designers, we clearly identified that there is a need to provide ergonomics data in a highly visual form that can be used efficiently in combination with existing design tools and practices. However, much of the published information is summarised in the form of guidelines. These are prescriptive evaluation tools rather than predictive tools which are necessary for supporting concept design. As most designers now use CAD tools extensively, it was considered to be highly appropriate to provide support for 'design for all' through this medium.

The use of 3D human modelling systems (such as SAMMIE CAD, RAMSIS, JACK, SAFEWORK) within the design process has increased significantly over the last decade. As such systems are not always used by experienced ergonomists, there are concerns that the computer human models may be treated simply as 'articulating components' of three different sizes – small female, average male and large male. This, clearly, is not the route to achieving 'design for all'.

DESIGNERS NEED TO PREDICT MULTIVARIATE ACCOMMODATION ISSUES

Whilst young and able people are often considered to be able to 'adapt' to a poor design, there is typically an associated human cost. For example, a poor posture that has to be maintained for prolonged periods will result in a high incidence of musculoskeletal troubles and possibly sickness absence. If important displays are not clearly visible or controls are difficult to operate, then safety will be compromised.

People who are older or disabled have less opportunity to adapt to a poor design. In many cases, they are effectively 'designed out' and cannot use the product or service. The 'design for all' philosophy aims to reduce, if not eliminate, such problems. Our interviews with a sample of 50 elderly people, in which we asked them how design could improve their quality of life, told us that being able to prepare meals for friends and family and being able to use local transport were the two primary areas.

So, let us consider Janet, an arthritic elderly woman who needs the support of a wheelchair, and who wants to improve her quality of life by cooking a meal for her friends. First, she may need to check her bank account and take out some cash and she would have to achieve the following general tasks: (a) gain access to an automatic cash dispenser located several miles from home; (b) view and interpret the screen, instructions and controls; (c) reach and operate the controls; and (d) reach to collect the cash and receipt. Will she be able to perform each of these tasks, let alone those of shopping and cooking? If Janet fails on one component task, then she cannot use the cash dispenser and she has been effectively 'designed out'. It is important that such multivariate issues are understood and managed when new products and workstations are being developed.

DESIGNERS NEED HOLISTIC INFORMATION

Information sources for designers are very fragmented. ‘Designing for all’ requires access to a large library of publications in order to compile information on the physical size and abilities of people of all ages. This is necessary so that the designer or ergonomist can construct a variety of 3D human models to represent the wide variety of envisaged users of the product or service being designed within a CAD system. Current anthropometric and biomechanics databases present information typically as univariate percentiles with a separate table of numbers for each variable, such as eye height, arm reach or hand grip strength. These percentile tables are prepared for either a healthy population aged 19-65 years or for specific populations, such as people who are older and with disabilities. Sadly, most of these databases do not promote the need for multivariate analysis.

Worse than that, many databases present data only for the male and female 5th, 50th and 95th percentile values for each variable. This effectively supports the designer (both practically and morally) in ‘designing out’ up to 5% of females and/or 5% of males for every important dimension of the product or workstation. Ignoring the lower and upper 5% categories for every critical dimension will lead to many people being designed out. For example, a woman with short arm reach will not necessarily also have slim hips or a weak handgrip; the man with long legs will not necessarily have wide shoulders or strong biceps. The typical presentation of anthropometric data as 5th, 50th and 95th percentile manikins does not convey this information and leads to the mistaken belief that designing from 5th percentile female to 95th percentile male will satisfy at least 90% of the population. This may be true for one important dimension, such as headroom, but not where several critical dimensions exist, such as when using a cash dispenser, operating equipment or driving a car. Roebuck et al (1975, page 268) perfectly illustrate the problem with using univariate percentiles. They document that nearly half of a population being designed for (cockpit design for aircrew) were actually ‘designed out’ when the 5th to 95th percentile range was used on a large number of body dimensions in a safety and performance critical workstation. The aircrew that were designed out because their backs were too long were not the same as those aircrew designed out because their legs were too short, their hips too wide, their thighs too long, and so on.

Statistical methods do exist which can be used by specialists to conduct multivariate analysis, such as Principal Component Analysis and Monte Carlo simulation. Both are complex and these approaches lack face validity, literally. Whilst many designers have doubts about the validity of combining different percentile body parts based upon statistical calculations, the fact that there are no actual faces that can be put to these anonymous statistical creations is a bigger problem. Designers need to have empathy with the people they are designing for – they find it difficult to design for statistical calculations. Empathy comes from seeing people and getting to know and understand their needs and desires.

The data also need to be task and environment specific. For example, when cooking the Sunday roast, Janet will want to hold the hot baking tray in two hands using oven gloves, not just with a simple one-arm reach as presented in existing databases. In addition, she will want to be able to balance the tray when lifting to avoid spillage. It is likely that Janet will have developed some ‘coping strategies’, which help her to carry out the various tasks in the kitchen. It would be most beneficial to record these and be able to pass this knowledge to the designer.



Figure 1: Designers can now 'put faces to data' with our computerised database of individuals.

PROJECT DELIVERABLES

As a deliverable of our grant, we have developed a CAD based design tool (HADRIAN) that consists of a multivariate database concerning the 3D anthropometry and functional abilities of a wide range of people, together with the methodology to exploit the use of such data.

Our novel approach is to create a computer database of 'individuals' so that multivariate analysis can be conducted on a wide range of real people of all ages, abilities, shapes and sizes. The traditional creation of tables of percentiles for each body dimension effectively dismembers the individuals – it becomes impossible to recreate the original individuals who were measured in the survey. Our approach is to preserve the information for each individual as a complete dataset. This literally enables us to 'put faces' to the data (see Figure 1) and makes multivariate analysis more straightforward, at least conceptually. To promote 'design for all', the designer needs to identify which of these computerised individuals are currently 'designed out' by a proposed prototype design, together with the reasons why, so that subsequent design modifications can be made that will include these people.

The database initially comprises 100 individuals, including a large proportion who are older and/or disabled. This sample, whilst not strictly representative of the whole population, provides a useful measure of the extent of variation in physical characteristics and capabilities

and provides a preliminary database for the development and validation of the predictive tool. Design relevant information concerning task behaviour (including coping strategies) and environmental issues have been recorded using test rigs to simulate typical activities of daily living that are known to be problematic for people who are older or disabled. We are currently seeking funding in order to increase the number of individuals and tasks that are included in the database.

The use of HADRIAN will enable the whole population, including those who are older or are disabled, to be considered when evaluating and optimising multivariate design issues. The computer based, multivariate database of individuals can then be accessed automatically during computer design work so that the percentage of people accommodated by a proposed design can be estimated based upon criteria for task success that are interactively set by the designer (e.g. access, vision and reach to important features of a design; mobility and strength required to perform a task). HADRIAN is integrated with the SAMMIE CAD human modelling system so that each individual dataset can be automatically tested to identify which individuals cannot achieve one or more of the criteria for successful interaction with the design. The designer will be able to ‘call up’ the data for these ‘designed out’ people and to simulate their problems by modelling their personal body dimensions and physical capabilities. This will provide the designer with important feedback so that further and iterative efforts can be made to endeavour to ‘design for all’. The tool will then support the designer in achieving a greater percentage accommodation, possibly involving more adjustment, modular components or a new perspective on the solution entirely.

A detailed description of the database and HADRIAN are given in the following two papers (Oliver et al, 2002; Marshall et al, 2002).

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