# Supporting 'design for all' through an integrated computer-aided ergonomics tool

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# SUPPORTING 'DESIGN FOR ALL' THROUGH AN INTEGRATED COMPUTER AIDED ERGONOMICS TOOL

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## 1    Introduction

The aims of this paper are:

- Provide a background to the Design for All (DFAll) philosophy and its importance to the design community

- Present some initial findings of a survey into the DFAll needs and desires of design practitioners

- Highlight a few specific details of an integrated computer aided ergonomics solution being developed in response to those needs.

It is well known that 70% of the cost of a product is committed during design yet only 5% of the cost is actually spent (Figure 1). Thus, the design phase of the product lifecycle, and therefore designers, are key targets for ensuring successful new product introduction [1]. The importance of methodology, process, and the provision of supporting tools are paramount in facilitating the designer's work. It is important that such tools are easy to use and are well supported themselves through the provision of appropriate data. It is also important that such tools are not only available but possess the features and functionality to be applied in key areas throughout the product development process and especially during the early phases of design. One of these key areas of the product development process is the consideration of ergonomics issues and the systemic view of how a product interacts with its user. Traditional approaches have seen ergonomics issues addressed at a relatively late stage during the product life cycle, where priority has been given to styling, cost, manufacturing and other such concerns over the user [2]. Clearly this approach is unacceptable yet it continues to be a factor within the product industry and will continue to be so until the education of designers and those who ultimately have responsibility for design promote the opportunities to be found in early consideration of ergonomics issues.

In addition to educating the designer in the efficacy of a timely application of ergonomics it is important to provide the correct information about the user and their needs. However, the traditional approach to this issue has seen the vast majority of products developed for the 'average' and able bodied population. One aspect of this issue is the way in which data is presented in percentiles. The percentile is a univariate statistic which refers to only one characteristic in isolation telling us little or nothing about other body dimensions [3]. As such product design for a typical range of the population might consider $5^{th}$ percentile female stature to $95^{th}$ percentile male stature. It would seem that our chosen range covers 90% of the

population. In reality an $x^{th}$ percentile has poor correlation between dimensions and therefore does not cater for tall people with relatively short arms or short people with relatively long legs, for example. To exacerbate this problem an increasingly large proportion of the global population is disabled or have functional limitations due to injury, illness or ageing [4]. The specialist requirements of these people are then left to individual customisations for individual types and degrees of impairment. The DFAll philosophy aims to educate designers in the importance, both socially and economically, of accommodating this increasing population. DFAll promotes a holistic approach focussed on product accessibility and usability aimed at providing products that meet the requirements of a larger proportion of the population. Such products would incorporate features that accommodate and appeal to able bodied users and those who are older or disabled, significantly reducing the need for bespoke designs and individual customisations.
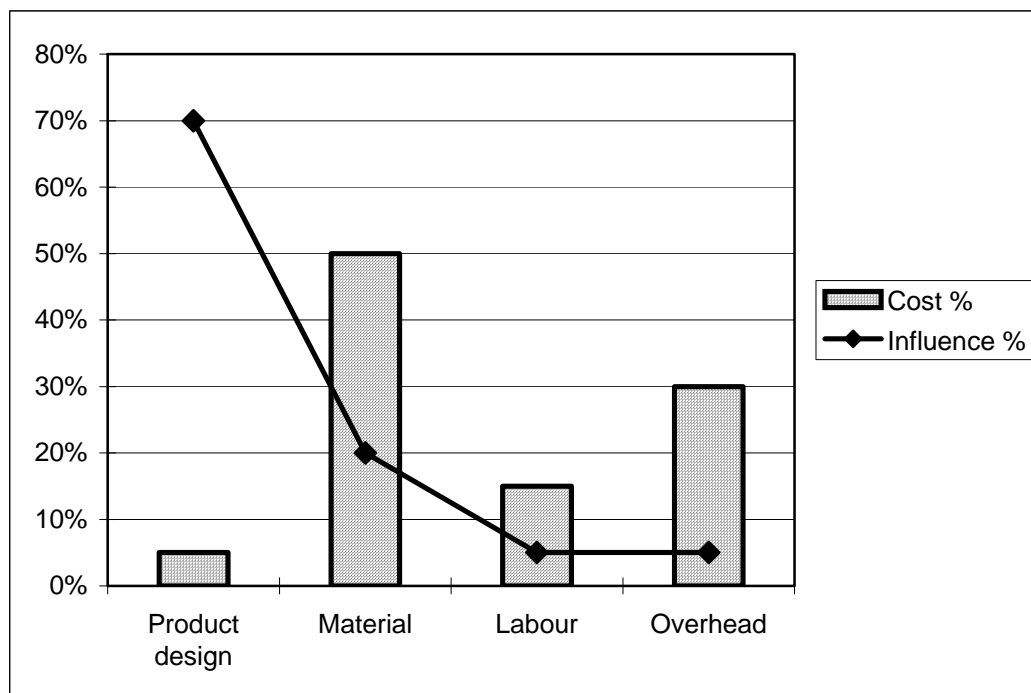


Figure 1. The Influence of Design.

The research described here aims to support the DFAll approach to the design of equipment, services, and systems by developing an integrated database and design tool concerning the 3D characteristics and abilities of people together with an efficient methodology for its exploitation in design. The focus is on the physical aspects of a particular design so that a broader range of the population can be considered when evaluating multivariate issues including access, fit, reach, strength and posture. An important criterion considered is the ability to predict the percentage of the population that will be catered for by a design, while the ability to determine who has been 'designed out', and why, is considered to be essential in improving the design [5].

## 2    The design community

To establish the current situation regarding design in relation to the philosophy of DFAll, a survey of designers and other professionals involved in the design process was carried out.

The purpose was to investigate existing products, procedures and systems. It was also important for the success of the design tool, to identify the needs of designers whilst attempting to 'design for all' [6]. Thus far 35 interviews have been carried out with individuals involved in the design process from students, through engineers, clinicians and design directors across a broad range of industries. Information was gained on issues such as the degree of awareness of DFAll or related approaches, current information sources, methodologies used, tools and systems used, knowledge of the user, and their needs with respect to meeting customer requirements. Initial findings include:

- Users are mainly involved in the design process during final testing, when the product form and functionality is largely set.

- Design teams rarely evaluate early prototypes or existing designs themselves with awareness of the different types of user and in the environment in which the product would be used.

- Design teams follow the specification placed by the client and, unless specifically requested, they do not attempt to include the needs of older and disabled people. For in-house designers these needs are also rarely considered unless the product is specifically targeted at that group.

- Available data tends to be difficult to find, inappropriate and often presented in a form difficult to adapt to the designer's needs.

- CAD is a widespread tool and due to its familiarity to those involved in the design process and usage throughout the product development process new forms of data and evaluative techniques should be integrated, or work in conjunction, with existing systems.

A qualitative analysis of the findings supports the premise of DFAll and also a broader need for improving the awareness and availability of appropriate information and tools in the ergonomics field especially related to those sectors of the population that don't fit into a stereotype of a 'normal' able-bodied user.

## 3   Methodology

The effective support of DFAll requires that data provided for use during the design process be presented in a form sympathetic to designers' methods which are dominated by computer aided three-dimensional modelling, visualisation and production systems. Three-dimensional data is required on a range of characteristics and capabilities across the population. Many databases exist that are concerned with such data, and in particular, anthropometry [2,7-11], but typically these sources provide very limited information on those who are older or disabled. Studies that do relate to these areas of the population are often very limited in sample size and/or relate to very specific conditions [12-14]. Computer-based human modelling systems such as JACK and SAMMIE [15] provide models that are capable of representing such information and applying it in design situations. The main limitation of these systems is that they require an inherent understanding of ergonomics principles and do not adequately represent people who are older or disabled. Thus, the intention of this research is to address the needs for improved information / data in conjunction with the development of an enhanced version of the 3D human modelling system SAMMIE.

In contrast to traditional *population data*, the data element of the tool will consist of a multivariate database of *individuals*, including those who are older and disabled. A range of data will be included for each individual including: anthropometric data, joint constraints, reach / grip related hand length, handedness and a range of descriptive data related to the individual's name, age, sex, etc. One hundred individuals, the majority of whom are older and/or disabled, are to be selected as representative of the real population and to provide a manageable preliminary database for the development and validation of the tools capabilities.

An initial sample of 100 individuals will be taken and used to create 3D human representations of the individuals; these human models will then be used to obtain feedback on the efficacy of a design through the use of virtual fitting trials providing predictions on fit, reach, vision and strength on an individual by individual basis. The tool then aids the designer by allowing the results of the virtual fitting trials to be interrogated providing data and a visual representation of the features or task elements that cause the greatest difficulty. This analysis will ensure that the designer focuses on the areas that are key for maximising the percentage of the intended population physically accommodated by the design.

Validation of the tool will be sought by comparison of its predictions with results obtained from a sample of individuals using test rigs. A prototype tool will then be demonstrated to designers at all levels and used in a number of case studies. DFAll workshops will be held to present and distribute results, obtain the views of a wider audience and elicit any concerns.

# 4    A Design Support Tool

The use of computer aided ergonomics systems during product development is a well-established methodology of which there are numerous examples [16]. SAMMIE, **S**ystem for **A**iding **M**an-**M**achine **I**nteraction **E**valuation is a long-established and typical example that has been used in a wide variety of applications [17] and forms the basis of the work described here (Figure 2). Human modelling systems provide the ability to construct 3d models from anthropometric data which can be articulated between the body segments to simulate a wide variety of postures. These human models can then be used in conjunction with a CAD model of the product being designed, to conduct computer based trials. Predictive results provide a much stronger emphasis on the need for sound ergonomic solutions during the design process and enable the designer to be more proactive in achieving user-oriented designs.

The approach taken in development of the tool's capabilities focuses on an integrated approach to supporting the designer in three key areas: data input and manipulation, task description and analysis, result reporting and analysis feedback. This approach then aids the designer in the evaluation of a specific design, establishing semi-automated virtual fitting trials through macro programming for the SAMMIE computer aided ergonomics system. This has evolved from some simple tasks using the tool and macro language into a basis for a generic design analysis macro with supporting data input and storage. This is being carried out in parallel with the survey and data collection aspects identified above and thus synthesised data is being used to develop the methodology.

To facilitate this process the task and its evaluation criteria are defined within an analysis set-up / configuration file. The file specifies basic information pertinent to the task e.g: the individuals to pass through the trial, the main task elements, the order of those elements, and some parameters for success such as acceptable viewing distances. The designer is guided through this set-up process ensuring that familiarisation is gained with the tool's operation but

also encouraging the designer to consider a user-centred approach to the evaluation. The system then interrogates these files for the analysis without the need for further user interaction. In this way the requirements on the designer using the tool are directed away from detailed knowledge of driving the SAMMIE system towards highlighting the fundamental ergonomics principles based in achieving a successful task analysis that accommodates the broadest percentage of the population.
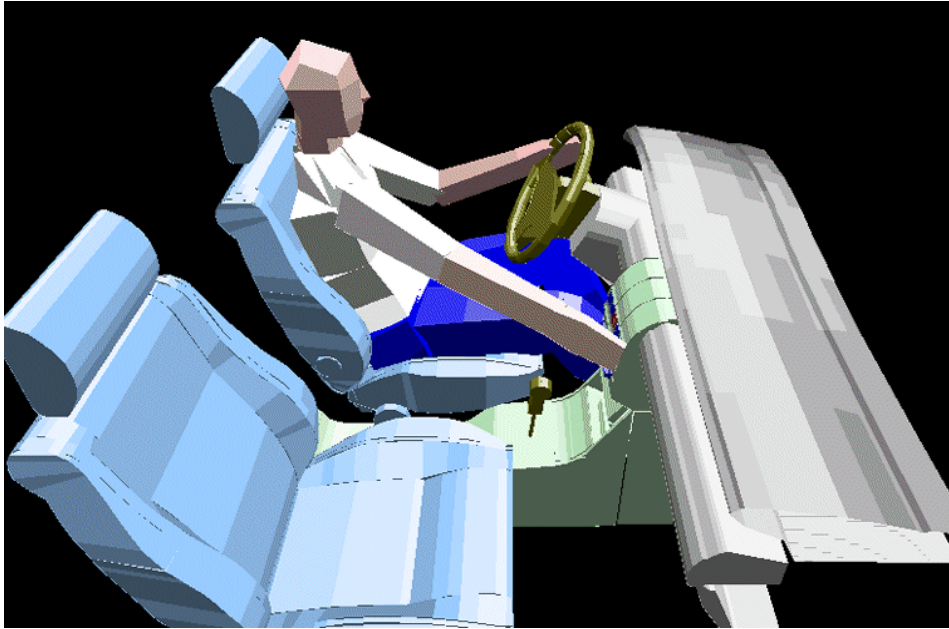


Figure 2. The SAMMIE CAE System.

In order to try to maximise the information provided by the results from the analysis the macro performs some simple logic and human model manipulation in order to overcome a failure in any of the task elements defined. This is an attempt to replicate the process by which a human operator would approach the task. The macro assesses the situation for each task element and determines ultimately whether the task is possible and what has had to be done to achieve it. This approach provides a much more useful set of results and feedback to the designer allowing individual elements of a task or design to be isolated and addressed in improving the overall accommodation achieved by the design.

# 5    A Case Study

As a working model, an automated teller machine (ATM) design has been used as a basis for the development of generic task analysis elements. The SAMMIE macro's discussed previously were used to aid in the process of specifying a set of virtual subjects (users) to run through the trial, defining the task elements and task parameters including: positioning of the user in an appropriate location to use the ATM, the various reach and vision checks to the card slot, receipt and cash dispensers, and screen. Finally the macro's provided results of the trials showing not only ultimate success or failure of subject vs. task but also vs. individual elements of the task providing a means to ultimately define the features of the design that aid or hinder accommodation. Further work is investigating object oriented methods for encoding model objects with information on how they are to be interacted with (grip locations, operational parameters etc.), formalisation of the task description, and modularisation of the analysis elements for generic application to any task.

Figure 3 shows a snapshot of one possible result of an analysis. In a task specified to analyse the usability of a typical ATM the location of various ATM features has led to a condition where the wheelchair user is unable to perform an element of the task. Ultimately the wheelchair user is not accommodated by the current design through an inability to reach the card slot. This result has been determined using a standard SAMMIE reach test augmented by the logic programming in the macro attempting to reposition the user in an attempt to achieve success. However, the only viable solution to ensure a positive reach test is restricted through a clash between the ATM and the wheelchair. To aid the designer in interpretation of this information, which in more complex evaluations may not be insignificant, the tool will also attempt to provide guidance on areas in need of attention or even specific solutions that would ultimately achieve a more accommodating design.



Figure 3. ATM Evaluation.

## Conclusion

The data from the initial survey of design professionals has confirmed the need for programmes such as design for all, promoting the needs of those who or older or disabled in the mainstream of product development. It is also clear that any successful approach to supporting those who work in product development must work around existing methods and complement existing practices. The initial software development of the design support tool has showed how this integrative approach might support designers and promote the ethos of design for all and ergonomics issues as a whole. It is expected that the tool will provide benefit directly to the design community but also to the education and research communities as a tool for promoting these issues in a broader context. Finally it is hoped that this work will ultimately foster the concept that products can be developed that meet the needs of the user regardless of place within the population without sacrificing image, quality and cost effectiveness.

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