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A COMPUTER AIDED ERGONOMICS TOOL TO SUPPORT ACCESSIBLE TRANSPORT DESIGN

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ABSTRACT: Accessible design is being promoted through concepts such as 'Design for All'. This is an approach to design that aims to maximise the accessibility of a product, environment, or service through the provision of a solution that accommodates the needs of all users including those who are older or disabled. To support a 'Design for All' approach a computer aided design and analysis tool called HADRIAN has been developed. Initial developments addressed the provision of accurate and applicable data on the target users together with a means of using the data for ergonomics evaluations during the concept stages of design. This paper details some of this initial development together with the current focus for the HADRIAN system, namely that of transport design. The novel aspect of this research moves the focus away from isolated design problems such as the accessible design of a train or taxi, onto the concept of the journey and the system of design problems that must be addressed in order to create truly accessible transport.

KEYWORDS: design for all, accessible transport, ergonomics, CAD

1. INTRODUCTION

'Design for All' or 'Inclusive Design' are terms that have begun to see widespread use in highlighting the significant social responsibility to address the needs of the increasing numbers of older and disabled people within the population, together with an increasing legislative and economic impetus to take this approach to design. Various sources indicate the extent of the ageing population and estimates suggest that world total will be more than 1 billion people aged 60 or over by the year 2025 [1]. Further estimates suggest that 36 million disabled people in the U.S. spend 40 billion dollars on special products and the population over 50 purchases 60% of all domestic cars and own 50% of all homes [2].

'Design for All' is an approach to the design of products, services or environments that focuses upon meeting the needs of the broadest range of users. This is a distinction from meeting the broadest range of user needs, as the focus is not necessarily on providing increased functionality but rather ensuring that any functionality is accessible to anyone who

wishes to use the product. Thus, the target is to provide an inclusive design that accommodates the needs of both older and disabled people together with younger and more able people, avoiding bespoke and customised products that target specific problems or disabilities [3].

From a design perspective the increasing number of older and disabled people is not a concern, good design will all ways meet the needs of its users. The difficulties lie in the potential exclusion faced by the older and disabled population due to poor, or just careless, design that has failed to take into account the needs of this part of the population. Research carried out into the experiences of older and disabled people in undertaking 'activities of daily living' (ADL), highlighted typical difficulties in achieving these fundamental, every-day tasks. Interviews were conducted with 50 older and disabled people about their own ADL. Of these people 42% had severe difficulties using the bath and around 20% had severe difficulties with performing kitchen tasks such as placing pans at the back of the hob, putting things in the oven or reaching to high shelves [4].

Our approach to these issues was the development of the software tool HADRIAN (Human Anthropometric Data Requirements and Analysis). HADRIAN consists of our novel database of individuals complete with data on anthropometry, joint constraints, capabilities, and behaviour stored as a complete set for each person. This database is integrated with our task based analysis tool aimed at providing a means for getting rapid ergonomics feedback during the concept stages of design in a manner that minimises the need for ergonomics expertise and expertise in the use of human modelling systems.

This paper introduces the initial stages of our research into developing the capabilities of HADRIAN to address the area of transport design. This research is being undertaken as part of the AUNT-SUE (Accessibility and User Needs in

Transport for Sustainable Urban Environments) consortium [5], part of the Engineering and Physical Research Council's (EPSRC) SUE programme in the UK. This consortium consists of members from London Metropolitan University, University College London, Loughborough University, Camden Council, Hertfordshire Council, and the RNIB, among others. The consortium's aim is to produce methodologies for sustainable policies and practices that will deliver effective socially inclusive design and operation of transport.

2. COMPUTER AIDED ERGONOMICS

Computer aided ergonomics tools such as human modelling systems; JACK [6], RAMSIS [7], SAMMIE [8] etc. offer considerable benefits to designers looking to design for all. Potentially, such systems can be used to model a broad range of users and their individual abilities. Combining these virtual users with a model of a proposed design allows assessments to be made into the suitability of the design. This process is known as a virtual fitting trial and is gaining widespread use in many areas of design.

However, whilst the use of these technologies can clearly play a key role in supporting design that is user-centred, there are a number of concerns in the current technology, data, and infrastructure used for computer aided ergonomics evaluations in design. Such concerns include [9]:

- Ergonomics data is difficult to access and difficult to apply especially when considered in the human modelling context
- Human modelling systems have to make compromises in creating valid human models from data that was not designed for this process
- The use of human modelling systems not only requires the user to be skilled in using the tool, but to also have ergonomics expertise in order to use the tool appropriately
- Human modelling systems invariably suffer from many of the issues that surround more traditional CAD systems in that they provide focussed support for downstream activity but still do not adequately address use at the concept stage when ergonomics considerations should initially be addressed
- The combination of statistical data and the virtual environment detaches the designer from any empathy they may have had with

the real person that the human models are meant to represent.

In addition to these generic concerns specific issues arise when products are aimed at users who may be older or disabled. Clearly, for products targeted at these sectors of the population the generic nature of the data available and the even greater lack of empathy with the very specific needs of these users often leads to compromises or incorrect assumptions being incorporated into the design.

Other, long standing concerns include the preference for ergonomics data to be presented in percentiles [10]. Whilst this approach attempts to simplify presentation and understanding it does not help in using the data for multivariate - task based analyses of products or environments. A further concern is the relevance of the available data. The majority of anthropometric and biomechanical data refers to younger able bodied populations. Data are available on older and disabled users [11]. However, many sources are of limited size or refer to very specific disabilities. Task based data is captured for standardised postures and activities. Whilst this is a pragmatic approach to data collection it often causes difficulties when the situation to be assessed falls outside of the standardised parameters. Such situations require assumptions to be made. For these assumptions to have any real validity they often require expertise and this is not always available especially if the process is taking place during the concept stages of design.

If we introduce further factors into the equation such as the data associated with subsets of the population such as older or disabled people, the validity of typical data is even more questionable. Correlation between measures is even less predictable, asymmetry may be a major concern and capabilities will vary considerably from the 'norm'. In addition, this takes no account of behavioural issues such as coping strategies that are employed by these people to allow them to complete tasks that data would suggest are not possible.

However, the ongoing developments in CAD could support a completely different approach. Storage and retrieval of large amounts of data is now trivial, the use of body scanning technologies allows many more measures to be taken with greater accuracy and repeatability in much less time. Advances in modelling the human form, whilst still very complex and constrained by long processing times, support a much more accurate prediction of posture and flesh deformation and provide the potential for improved task analysis simulations [12].

There is also the potential to combine these data with new tools to simplify their application and support the designer in evaluating their designs in a much more interactive, intuitive and valid manner.

3. HADRIAN

HADRIAN (Human Anthropometric Data Requirements Investigation and ANalysis) is the name of our computer aided ergonomics tool aimed at addressing some of the issues highlighted in supporting the designer when designing for all. HADRIAN was initially developed as part of a three year research project as part of the EPSRC's EQUAL programme. EQUAL was initiated by the UK Government's Office of Science and Technology in 1995 to draw together research activities that bear on

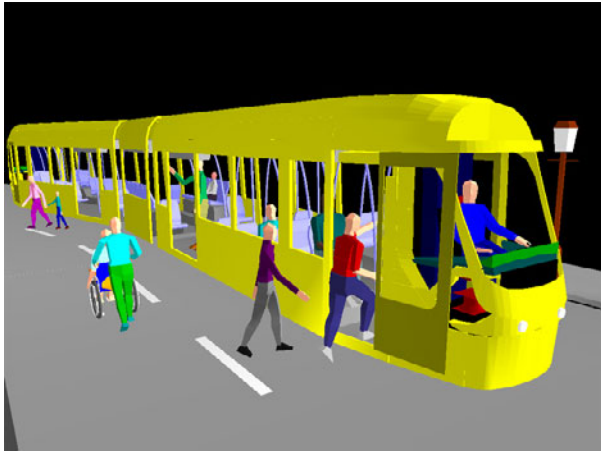


Figure 1. The SAMMIE system.

the extension of the active period of people's lives, thereby helping individuals to achieve a better lifestyle and avoid or alleviate the effects of disability. Since January 2005 initiatives stemming from EQUAL have led to the development of SPARC (Strategic Promotion of Ageing Research) which is promoting research in a number of areas to further improve the quality of life of older people [13].

HADRIAN has been developed to work with the existing computer aided ergonomics system SAMMIE (Fig. 1). Together these systems provide the capability to investigate data on individuals in addition to allowing task analysis and virtual fitting trials to be carried out on a design without the need for prototypes and user trials. However, it is not the intention to replace physical models and user trials but rather to complement them. HADRIAN provides the designer with a means of performing this kind of analysis, and getting a feel for some of the types of feedback that might be achieved through these processes, at an early stage in the design when the time and costs for real trials are prohibitive.

3.1 Database of Individuals

The HADRIAN database consists of physical and behavioural data on 100 individuals covering a broad range of ages and abilities [14]. The sample is deliberately skewed towards the older and disabled population to offset the relatively well understood younger / able bodied population. Data is available

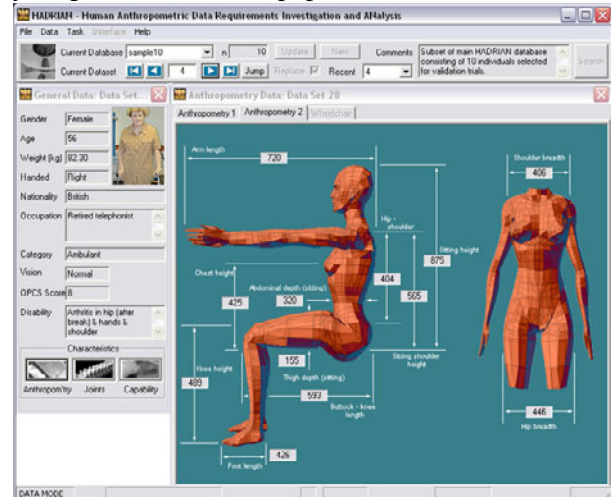


Figure 2. The HADRIAN database.

on external anthropometry, joint constraints, background information and also notes on any disabilities and problems experienced with activities of daily living. The system also contains more novel data on link (bone) lengths and functional reach i.e. a comfort limit based reach with grip (Fig. 2).

In addition to the range of anthropometry and joint constraints the system also contains task based data. This covers a range of kitchen based tasks and a number of seating scenarios which can also be broken down into more generically applicable elements. Where possible data reflects the real-world experience. Thus, comfort maximums were recorded to reflect what the subject would be likely to do in their own home where absolute maximums would not normally be used. In addition, tasks that represented hot loads such as lifting items into and out of the oven were performed using oven gloves to represent their affects on capability and behaviour.

Task data stored within HADRIAN includes a success or a failure for each task element. In addition, that data not only records whether a task was completed, but also how it was completed. This behavioural element is a key part of the HADRIAN mechanism for predicting accurate postures in task situations. It could be argued that as long as the system predicts postures that the individual could adopt the results would be valid and useful. However, older and disabled people often develop

coping strategies for dealing with their reduced capability. These coping strategies make it much less predictable what an individual might do and subsequently what they might be capable of for any given task. Thus, we believe it is equally important to capture and then predict the capability and behaviour of an individual in a virtual fitting trial.

3.2 Task Analysis Tool

Whilst a significant part of the HADRIAN tool is the integrated, intuitive and significantly more applicable database, HADRIAN was also designed to support the use of the data within ergonomics evaluations. A particular focus of this support is targeted at concept design. Typically, any ergonomics evaluations at this stage must be computer based as designs are not sufficiently mature during concept design to warrant physical mock-up and user trials. Even if it was possible it would rarely be practical or cost effective. However, whilst the tools exist to perform ergonomics evaluations in the CAD environment, through the use of human modelling systems, they suffer from the same data concerns discussed earlier. A particular issue is the expertise required to perform the evaluation and actually drive the system. Finally, recent developments have seen human modelling systems integrated into mainstream CAD systems. Whilst this is efficacious during detail design these systems still have many difficulties to be addressed for concept design, thus by combining the two the process almost legitimises leaving the use of ergonomics evaluations to the detail design phases of product development.

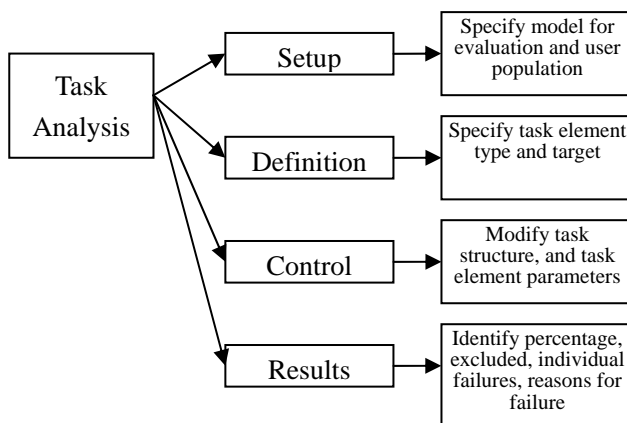


Figure 3. Layout of HADRIAN task analysis.

To evaluate a design HADRIAN provides a mechanism to define a task that the individuals in the database will then try to perform with the design being evaluated [15] (Fig. 3.). To make the task definition process manageable the task is broken down into

segments, or task elements. Task elements consist of a range of physical activities generally supported by human modelling systems such as reach and vision. Once an activity has been selected the system will also normally require a target, where targets are interactive

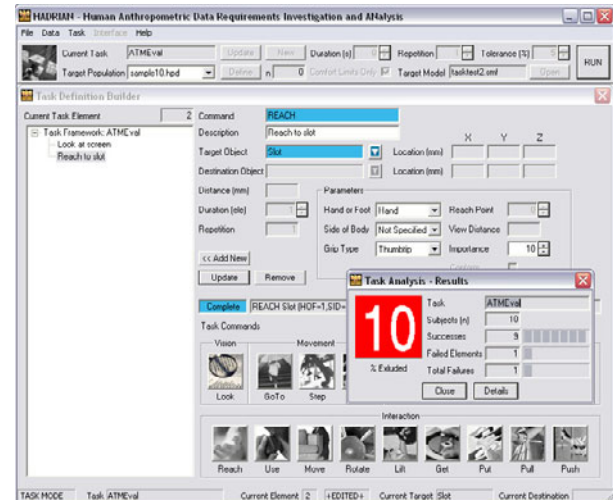


Figure 4. Task analysis in HADRIAN, showing analysis results.

elements of the design to be evaluated. Finally there are a number of activity specific parameters (view distances, grip types etc.) that can be specified if desired or left for the system to determine.

Having defined the task the designer can then run the analysis. Running an analysis will create a human model for each of the individuals in the database with their appropriate anthropometry, joint constraints and a codification of their behaviour within the SAMMIE system. These individuals are then used to perform an ergonomics analysis on the chosen design. Upon completion results are displayed that include the number of individuals excluded from using the design due to failure of one or more task elements. In addition, the actual individuals who are excluded are identified so that the designer can learn what characteristics of the design and its interaction with the user cause difficulties. Having evaluated the results the designer is then free to make changes to the design and rerun the analysis without having to redefine the task and so can quickly test the affect of any changes on the percentage excluded (Fig. 4).

4. AUNT-SUE

The initial development of HADRIAN addressed localised design problems in response to user feedback, for example the design and layout of a kitchen or the design and placement of an ATM. As

part of the AUNT-SUE project HADRIAN is to be developed further, to broaden the content of the database and to increase the functionality of the task analysis to incorporate transport-related data.

The system will still work with a prototype database of 100 people. Their existing data will be supplemented by additional transport and travel related task data. A comprehensive data set for collection has yet to be confirmed but it is likely to include data on ingress and egress of a range of



Figure 4. Transport related tasks for future HADRIAN development.

vehicles such as taxis, trams, trains and buses. This will also include a range of step types to reflect the variety of outdoor steps: steps from kerbs to vehicles, steps from platforms to trains etc (Fig. 4). Additional data will be collected on door releases, seating, ticketing machines, public toilets and general barriers and obstacles found in public places.

In addition to this physical data it is also likely that we will begin to accommodate cognitive data, looking at the individual's ability to deal with route planning, dealing with crowds, understanding signs and other public information under conditions of high visual noise, and issues with lighting. All of these elements are complex problems to understand and in particular to manipulate into a useable data resource. However, they are often some of the most fundamental issues when people are excluded. Thus a perfectly well designed ATM may well fail to be inclusive due to the dark and secluded location dissuading users from attempting to access it. Alternatively a perfectly accessible train design may exclude users who cannot reach the train due to poor signage.

4.1 Whole Journey Approach

The concept of accessible transport is not related to any single design problem; rather it concerns an infrastructure consisting of many design problems. Some of these problems are directly related, some indirectly, but all will need to be considered if accessible transport is taken in the context of the 'journey'. If we take the approach that accessible transport is there to enable users to travel from one place to another, such as from home to the doctor, from the bank to the theatre, or from the airport to a relative's house, then we need to consider all of the elements of this journey. Such elements may well involve many accessible design problems: kerbs, pavements, slopes, steps, street furniture, cash dispensers, ticketing machines, lifts and escalators, toilets and so on. All of these elements may be interacted with in the course of making a journey and if any one prevents the user from achieving a relatively small part of the overall task it may well prevent the journey from being possible.

It is intended that developments to the HADRIAN system will take the whole journey approach. The accessibility of individual designs will be taken in context of the journey and the user will be able to evaluate the accessibility of a particular journey rather than have to consider each element in turn. This approach provides a much more realistic evaluation of the social inclusiveness of any transport system.

To validate this approach two test-bed sites have been identified, in the London Borough of Camden and in the County of Hertfordshire, both of which have council representatives on the project. These will be used to identify areas of social exclusion and any existing accessible design problems that may feed into data collection. In addition, these areas will also be used to identify typical journeys that can be used as case studies for validation of the HADRIAN developments.

5. CONCLUSION

HADRIAN has been developed to support the design process by addressing issues with the data available for ergonomics evaluations, particularly that related to older and disabled people and the means in which the data is used. Work to date has proven the concept and provided prototype evaluation tools together with a limited database of individuals.

The AUNT-SUE project will further the development of the HADRIAN system by strengthening the database with a broader range of task data, reducing the number of assumptions that the

system has to make and making the data much more generically applicable. In addition HADRIAN will be developed to address not only isolated design problems but also system design problems by introducing the ability to evaluate all of the designs that will be interacted with during the course of a journey.

It is fully acknowledged that addressing the proposed functionality, particularly the combination of both physical and cognitive ergonomics, poses many challenges. However, the potential to provide a system that contains a virtual group of one hundred individuals ready to assess the accessibility of a complete journey, including the environment, the transport and the additional facilities such as ticketing machines, is a significant step towards ensuring that designers are fully supported in their attempts to design for all.

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