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A TASK BASED ‘DESIGN FOR ALL’ SUPPORT TOOL

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ABSTRACT

The ‘Design for All’ philosophy promotes the development of products that meet the requirements of a broader section of the population, including those who are older or disabled, to minimise the need for bespoke designs and individual customisations. Such an approach begins to meet the needs of a population containing an ever increasing proportion of these excluded groups, whilst providing opportunities to manufacturers to maximise the available market for any given product.

Most design activity embodies some form of task analysis that involves identifying users and the tasks they perform. Computer based human modelling systems are becoming increasingly important in this task analysis role combined with the established ergonomics technique of fitting trials, in which a product or environment is evaluated through trials using a carefully selected user group.

This research addresses the lack of existing data necessary for the accurate representation of human form and capability in the older and disabled populations for use in these modelling systems. A small-scale survey is being undertaken to collect this important information. In addition, existing modelling systems in this area rely on expert ergonomics knowledge in performing task based analysis, which in addition can be a time consuming and repetitive task. Methods are being developed to streamline this process and to place the emphasis on good design and ergonomics principles as opposed to ‘driving’ the system. These methods involve the development of a simplified process for computer based task analysis and a means of determining the percentage accommodated by any given design.

Further research will eventually focus on extending the data collection, refining the task model and look at a means of suggesting design solutions in response to the analysis results.

KEYWORDS: Design, Ergonomics, CAD

1. INTRODUCTION

It is reported that by the year 2005, there will be 10 million older and disabled people in Europe alone, some 25% of the total European Population, [1]. With such a change in demographics, it is becoming essential that designers address the requirements of this increasing proportion of the population and have access to information on the anthropometry and capabilities of the whole population of people who may wish to interact with the design in question. However, it is well known that products are not always designed to include the growing needs of the growing numbers of these groups [2].

The 'Design for All' (DFAI) philosophy aims to educate designers in the importance, both socially and economically, of accommodating this increasing population. DFAI 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. It is recognised that this objective is ideal rather than totally achievable and inevitably there will be those relatively small groups that will require products that are not attractive to mainstream markets. However, increasing the accommodation of diverse populations and gaining a greater understanding of the reasons why some are excluded remains a major aim and forms the basis of the research reported here.

Understandably many of the requirements in this area relate to activities of daily living (ADL). These include all the activities that define an individual's ability to maintain independence and thus are extremely important in a DFAI context. Despite this, studies such as Ashworth et al [3], give an 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 ADL. It has also been suggested that consumers are slow to complain about poorly designed goods and services and tend to blame their own loss of ability when they encounter difficulties.

1.1 EQUAL

The EQUAL (Extending Quality Life) Initiative was initiated by the UK Government's Office of Science and Technology in 1995 to draw together research activities that bear on 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. The potential benefits are twofold: improved health, a more active and better quality of life, and a greater continuing participation in society; coupled with a lighter burden on society, and the generation of considerable business opportunities for UK firms to exploit in global markets. Although benefits will accrue to all, the main drivers for the initiative are the needs of an ageing population, and the needs of people with disabilities [4].

The EQUAL programme has focussed on three areas: Built Environment, Design for All and very recently, Rehabilitation. The Built Environment addresses the design of the home, public buildings, spaces, and transport systems. Rehabilitation covers both rehabilitation informatics and assistive technologies. Design for All, aims 'to generate the knowledge base to extend the range of application of equipment, services and systems designed for the general population to people with disabilities through the development of the 'design for all' approaches. The programme aims to identify the needs of designers and commissioners of product and service design for data sets and information relating to

capabilities, including in particular those of older and disabled people, to define generic design methodologies and developing suitable design aids and design guidance for the many designers for whom design for all will represent a radical shift in design practice, and the provision of guidance on the need for and process of user involvement in design in the context of a wider user group’.

Clearly the research documented here aims to support the DFAll approach. Primarily through the development of computer based system comprising an integrated database of 3D characteristics, capabilities and behaviour of people together with a tool to support the use of this data within the design context. The focus is on the physical aspects of a particular design so that broader range of the population can be considered when evaluating multivariate issues including access, fit, reach, strength and posture [5]. The work will address the need to focus on the principles of good design and ergonomics as opposed to ‘driving’ the system and will provide tools to aid in the prediction of the percentage of the population that will be catered for by a design. Ultimately there is a need to determine who has been ‘designed out’, why, and what changes can be made to improve the design in this regard.

1.2 Multivariate Issues and Data Requirements

In addition to promoting the DFAll concept to designers it is important to also provide appropriate support through the availability of the necessary information about the user and their needs. However, databases concerned with appropriate data in this area such as anthropometry and human capability [6-11], typically provide only very limited information concerning people who are older and disabled. Data collected that is relevant to those older or disabled tend to be of limited sample size and relate to very specific conditions [12-14].

Another aspect of this issue is the way in which anthropometric 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 [15]. For a given design, analysis of access, reach, vision, strength and mobility may all be paramount in determining the accommodation of an individual. As such, analysis of a design for a typical range of the population might consider 5th percentile female stature to 95th percentile male stature. It would seem that our chosen range covers 95% of the population and it is therefore reasonable to assume that the accommodation of a significant proportion of the population has been addressed. In reality an xth percentile has poor correlation between body dimensions and therefore does not cater for situations that occur all too frequently such as tall people with relatively short arms or short people with relatively long legs and a short trunk.

It is the intention of the research to create a database that addresses these issues through the collection and storage of multivariate data on individuals. The initial sample will be a modest 100 people, the majority of whom are older and disabled. Data will be collected in order for the individuals to be modelled and to be used within task based analysis of product, service and system designs. This will provide a preliminary data set for development and validation of a predictive tool for estimating the percentage accommodated by a design. It is also recognised that there will be a need for a much larger survey in the future.

2. SURVEY OF CURRENT PRACTICE

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’. 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. DATA COLLECTION

3.1 Multivariate Database

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 on various body dimensions, joint constraints, reach / grip related hand length, handedness and a range of descriptive data related to the individual’s name, age, sex, etc. In addition, data will be collected on task-based capability such as reach envelopes and a set of generically applicable task analyses such as pick and place operations around the home or supermarket. Finally data will be collected on behaviour, and in particular, coping strategies that individuals will employ in order to complete a task, examples of which include sitting on a stool for kitchen tasks or kneeling down whilst placing or retrieving items from an oven.

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. DFAII workshops will be held to present and distribute results, obtain the views of a wider audience and elicit any concerns.

3.2 Pilot Study

Prior to the full study, it was decided to conduct a small pilot to refine the process for data collection, to fully understand all the issues regarding data collection especially when dealing with older and disabled subjects, and to test a number of differing data collection methods. The pilot study was held over the course of a week with eight subjects each scheduled for a two hour time slot. The eight subjects consisted of two younger able-bodied people, two older people (63 years +), two ambulant disabled people and two wheelchair users. For each pairing there was an even split of one female and one male subject. The data collected consisted of five main sections:

- General information on name, age, sex, weight, occupation, history of disability (if any) etc.
- Anthropometry and flesh depth measures. Two approaches were taken, one consisted of measuring body dimensions using easily identified bony prominences and landmarks, the other was based on anatomical definitions of determining joint centres for each major joint.
- Joint constraints. Comfort angles taken orthogonally for each joint of the upper limb.
- Reach envelopes. A definition of the volume described by the motion capability for the upper limb.
- Task based capability and behaviour for simple kitchen pick-and-place tasks at three standard kitchen heights (lowest oven shelf, worktop, lowest wall unit shelf).

Fig. 1. Subject performing reach envelope test.

The five sections were then split between traditional data collection methods including the use of a stadiometer, sitting height table, anthropometer, goniometer, tape measure, 30cm rule, a reach envelope board, video and digital still camera, and a more technologically advanced approach using CODA, a real-time motion capture system. The CODA system involves the use of small markers and control boxes that are located on the body in the desired location. These markers are then identified and tracked by a number of CODA machines. A single CODA machine is capable of tracking a marker in 3D space but in order to increase the field of view of the system, two CODAs were linked together for the pilot. Figure 1 shows a subject performing the reach envelope analysis using the traditional reach envelope board. Arcs are drawn with the body at various angles to the board, providing the volume described by the reach capability for that particular arm. Figure 2 shows the same subject complete with CODA markers performing the task study.

Fig. 2. Subject performing task simulation with CODA data collection.

The pilot data is still under analysis so no definitive data can be released on the comparison between the data collection methods but it is clear that collecting data in this manner is appropriate and that the protocol defined for the pilot is sound. Participants were very understanding and supportive of the work in general and were keen to be involved. Issues with mobility, stamina and capability of the older and disabled subjects was handled by taking a pace from the subject themselves, allowing sufficient breaks and being able to take the majority of the data whilst the subject was seated. In addition the data was all captured using comfort limits, as maximum limits, whilst interesting, would rarely be used in common everyday tasks.

4. A TASK BASED 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, System for Aiding Man-Machine Interaction Evaluation 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 3). 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.

Fig. 3. The SAMMIE CAE System.

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.

4.1 Task Definition Model

The next stage of development involves the definition and implementation of a fully capable task definition model. This model consists of a number of elements to allow a more task based approach to be used in driving the analysis tool, and to provide the system with the capability of approximating reality by examining task strategies and examining the process of adaptation when various task elements break down due to failure. The main aims of the task model include:

- Develop a means of describing a task using understandable terminology, rules and data.
- Provide tools to aid in the construction of the task description.
- Develop an analysis strategy that implements the task description within SAMMIE
- Synthesise an analysis macro from the analysis strategy and a set of modular SAMMIE command macros.

4.1.1 Approach

Whilst a task is essentially a dynamic process the approach taken is to determine key-frames, or essentially static snapshots, of the task on which to base the analysis. SAMMIE provides the functionality to model the elements of these static snapshots, namely: a posture for the human model, a target object, and an environment. Therefore, the main requirement in the development of the task analysis tool is the way in which the collected data is used to determine a suitable and realistic posture for the key-frame. SAMMIE already contains some tools to aid in the process of determining posture for task related elements such as reach in addition to a number of standard postures. Though these tools are not a complete solution they provide a means of achieving the desired outcome with some additional manipulation based mainly on behavioural data and its codification in SAMMIE macros. A further consideration in providing a realistic static simulation of a dynamic environment is to provide a task framework. This task framework will be used to provide the system with information on how task elements interact such that any particular key-frame posture is optimised related to the previous and future key-frame postures.

4.1.2 Task Elements

Tasks are essentially combinations of task elements relating to posture, the environment, and a set of task parameters such as duration, repetition, and the overall structure of these components. In order to understand and manipulate these elements the posture of the human model must be analysed and broken down into mechanisms for achieving this posture. These mechanisms can be defined as follows:

- Vision: position of head, neck and eyes in order to successfully view the target.
- Reach: position of hand, forearm and upper arm (or foot, calf and thigh) in order to reach the target.
- Attitude: position and orientation of other body elements to aid in vision and reach mechanisms.
- Posture: default postures as an initial component of the overall posture.
- Location: position and orientation of the human as a whole.
- Sequence: a manipulation of the vision, reach, attitude, and location posture elements taking into account the previous and future postural key-frames. Sequence may also take account of loading / strength factors and their influence on the overall posture.

Having outlined a set of posture mechanisms, and assuming the environment to be known (modelled), the task definition is completed through the specification of task parameters. The following task parameters have been identified:

- Duration: how long (time) the task is to be performed for
- Repetition: the number of times the task is to be performed
- Tolerance: a percentage of the of the task element success value that can still be considered a success e.g. with a view distance set to 800mm, a tolerance of 10% allows up to 880mm.

An additional concern is the requirement for two levels of task definition. A user will describe a task through a statement of 'what' is to be achieved. However, the system requires details on 'how' the task is to be performed, or be able to synthesise 'how' from existing data.

The outcome of these definitions provides a set of user level commands and appropriate parameters and a set of system level interpretations. The full set of these is beyond the scope of the paper but an example is shown below.

Command: TRACK.

The TRACK statement ensures the human model keeps the specified target in view for the duration of the task or for a user-specified period.

Syntax:

TRACK *target* [parameters]

Example:

track ball (GTE=(3), VAL=4000, IMP=10)

States that a system view check must be made of an object named ball, that the ball will be tracked for the whole of the task, that the maximum view distance is 4000mm, that task element 3 cannot be completed until the ball is successfully viewed, and that this task element has the maximum overall importance.

4.1.3 Task Framework

Whilst the approach to the task definition consists of a series of static elements the dynamics of the task are considered through the task framework. The task framework is an attempt to replicate the effects of one task element on consequent and subsequent task elements. Thus the framework adjusts how a task element is performed with the knowledge of the requirements for the next task element. Adjustments that are likely to be made include the orientation and location of the human model, its posture, and any strategies used by the system to try to complete a task element.

The framework is based on information given during the process of task definition. From the task description the framework specifies the number of task elements, which of those elements are dependent on each other and in what way. The framework also identifies all of the objects that are *targets* of the task elements and creates a map of the main areas of activity. The system process to develop the framework consists of the following steps:

1. From task definition determine number of task elements.
2. Scan the task definition for those task elements that are linked through the *gate* parameter and build a framework map (Figure 5).
3. Scan the task definition for the *duration* parameter and add this to the framework map.
4. Identify all *target* objects and collect their locations from the model. Analyse their layout and determine the location and orientation for the human model:
 - Overlay a 2m by 2m grid on the environment
 - Identify the 'working' grid areas (i.e. those that contain an interaction)
 - Weight the working areas according to the number of task elements per grid and duration
 - Determine human model locations and orientations for task elements:
 - Check weighting and adjacency of each grid. For adjacent and equally weighted grids adopt a mean location and orientation. For adjacent and non-equally weighted grids bias the location and orientation towards the greater weighting. For non-adjacent grids start a new location and orientation.
5. Collect *target* interaction specifics (e.g. hand to use) from the task element *targets*. Refine the framework map accordingly.

5. CONCLUSIONS

The initial survey of design professionals confirms the need for programmes such as design for all, promoting the needs of those who are 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 also provide the appropriate tools and data to back-up design for all efforts. The pilot data collection has provided an early indication of the issues of data collection especially when dealing with older and disabled subject and analysis is ongoing of the data on which to make a decision as to the most appropriate collection methods. The integration of the data and a task-based approach has begun through the development of a task definition model aimed at providing the designer with control of any analysis yet automating the process beyond the setup. The initial software development of the design support tool has shown 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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