THE DEVELOPMENT OF COMPUTER VISUALISATIONS OF OLDER PEOPLE AND DISABLED PEOPLE TO INFORM AND INSTRUCT THE DESIGN OF PRODUCTS AND LIVING SPACES

G. Jenkins, L. Mahdjoubi
Faculty of the Built Environment, University of the West of England, Bristol, BS16 1DD
Email: Gavin.Jenkins@uwe.ac.uk

ABSTRACT: Despite recent changes in legislation, poorly designed environments and products continue to proliferate and exclude the needs and requirements of disabled people and older people. Designers need to have an in-depth knowledge of human functioning if they are to create and sustain environments and products that include the needs of all users, allowing disabled and elderly people to lead full and productive lives. Anthropometry has traditionally been seen as the means by which this information can be made available, although its ability to accurately characterise human function is limited.

This research is developing characterisations of disabled people using motion analysis for the development of Digital Human Models (DHM) for use by designers and clinicians. The integration of DHM's with 3D visualisations of products and living spaces, will allow real-time simulation and interaction; testing a product or environments' performance prior to construction and therefore avoiding the need for expensive 'mock ups'.

Keywords - digital human models, disability, older people, environment, product design

BACKGROUND

The social model of disability has undoubtedly been the dominant paradigm in researching and understanding disability in recent years. Since being conceived and refined in the 1980s (Oliver, 1990) it has become increasingly influential as an alternative to the traditional model of disability as a personal medical tragedy. The social model of disability is based on the principle that disability is a denial of civil rights caused by the exclusion of disabled people in all facets of society. It also redefined disability in terms of a disabling environment, repositioning disabled people as citizens with rights and reconfiguring the responsibilities for creating, sustaining and overcoming disablism. This paradigm demedicalises disability and presents it as a social issue about universal rights.

A pivotal component of this is the extent to which the physical and social environment oppresses disabled people, because their needs and requirements are neglected. During the past few decades accessibility has become a major issue, mainly because of the political influence of growing numbers of older people and more positive attitudes to disability in general (Blackman, 2003) Demographic information (National Statistics, 2002) indicates that the population is aging. Gant (1997) draws attention to the increasing prevalence of disability associated with an ageing population. He argues that, discounting social responsibility, in purely commercial terms it is crucial that those involved in forming and shaping our environments and product ensure that they are suitable for older users and disabled users (Gyi, 2004)

A further emerging paradigm or concept of note is 'inclusive design' or 'universal design'. This design philosophy is replacing such terms as 'accessible design', 'design for special needs' and 'disabled access' in addressing accessibility. Originally articulated by Ron Mace, an architect at North Carolina State University, it can be defined as 'the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design' © Copyright 1997 NC State University.

The intent of universal design is to simplify life for everyone by making products, communications, and the built environment more usable by as many people as possible at little or no extra cost. Its uniqueness is the omission of any reference to disabled people or older people, it embraces that people are all different but share aspirations – to participate in society and to belong. It makes no arbitary division between people but is informed by an understanding that access is about and for everyone.

Significant legislative changes have occurred in many countries to help accomplish the goal of inclusion. The United States of America is currently viewed as having the strongest legislative framework in terms of the removal of barriers to inclusion, the forefront of this being the Americans with Disabilities Act (ADA), which was enacted on July 26, 1990. (US Government, 1996). Within the United Kingdom the Disability Discrimination Act (DDA), enacted in 1995 is bringing about increasing consideration of services and access for disabled people. The rights of disabled people to work, travel and do business are now legally recognised.

However while these legislative initiatives are requiring the needs of people with disabilities to be considered in the design of spaces inhabited, as yet, there is no statutory requirement to design products that are usable by all and this therefore continues to present significant barriers to those whose function is diminished or altered.

Clark et al (1990) in their study of older people and disabled people found that 53% were unable to shop and 45% were unable to prepare meals. A study by Ashworth et al (1994) gave a further indication of the extent to which older people and disabled people were being 'designed out'. They reported that 21% of their sample of 65-74 year olds and 55% of 85 year olds had at least some difficulties with activities of daily living. More recently, a study commissioned by the Consumer and Competition Policy Directorate of the Department of Trade and Industry in the UK demonstrated that large numbers of disabled people have difficulties when using everyday consumer products (Feeny, 2000). These are products that might be considered essential for everyday use such as those involved in food preparation, laundering and cleaning the house.

There is an urgent need to incorporate all end-users in the design process to ensure that environments and products are designed in such a way that they are easy, convenient and safe to use. Designers and architects need to move away from a reluctant compliance approach to the inclusion of older users and disabled users and discover the rewards in designing for real people rather than misleading stereotypes – able bodied and disabled people.

If designers designed products and environments within the functional abilities of elderly and disabled people then such consumers could use them easily and effectively and more safely. Moreover if such products are usable by disabled people then they would also meet the requirements of non-disabled people.

STATEMENT OF THE PROBLEM

Despite some progress in this field, inadequately or poorly designed environments and products continue to impose barriers to disabled people and older people. In order to create and sustain environments and products that allow people with disabilities to lead full and productive lives, designers need to have an in-depth knowledge of human functioning in the performance of tasks, allowing them to incorporate the needs and requirements of people with disabilities within the design process. They require an understanding and useful characterisation of the functionality of people with disabilities so that these can be incorporated into the design process.

Anthropometry data sets are one way of bringing the physical dimensions of users into the design process. However Gyi et al (2004) highlighted the limitations that data presented in this way has for design teams. For example the mode of presentation, primarily as tables and lists, requires reading and interpretation; the lack of support for promoting multivariate issues; and the lack of holistic information, such as task specific behaviours and environmental factors impede their use. In addition, data handbooks, such as Neufert, (1980) provide design guidelines based on anthropometric data which, often neglects the specific characteristics and needs of people with disabilities.

A further limitation of anthropometry data is that the information sources are often fragmented, making it difficult for the user to locate and compile relevant data. The most comprehensive anthropometric studies, including the Army ANSUR data, (Gordon, 1989) are focussed on non-disabled adults, with much of the work originating from work performed on military personnel. Studies that include children, older people and disabled people are scare and generally involve much smaller sample populations with fewer measurements, despite the fact that the physical characteristics of these groups are very different. (Anon, 2004).

Bradtmiller (1997) argued that while there is a great deal of anthropometric data in existence, due to variation in dimension definitions and measurement techniques any attempt to combine them into a useful database would be futile. As a result of this, government agencies and researchers have devoted a great deal of attention and resources towards understanding the physical abilities of disabled people.

In 1999 the National Institute on Disability and Rehabilitation Research (NIDRR) in the US requested a study to develop a prototype anthropometric database of wheelchair users as part of its Rehabilitation Engineering Research Centres (RERC) programme and in 2002 the Access Board (US Architectural and Transportation Barriers Compliance Board) funded a multi-year project to provide anthropometric information that could be used to help determine the space requirements necessary for users of mobility equipment.

Similarly, in the UK, an anthropometric study of over 700 wheelchair users to provide information about space requirements and weights of wheelchair users to inform the design of buildings and transportation systems was completed. (Stait et al, 2000). Steinfield (2004), however, stressed that anthropometry leaves some significant gaps in our knowledge about how people with disabilities interact with the environment and the products they use. Anthropometric research focuses on measuring body dimensions (structural measurements) and general human performance abilities (functional measurements). However this data cannot always be applied directly to design problems. Structural measurements are not sufficient to understand how a body moves in space and functional measurements, like reach envelope data, do not provide information about the adaptations that people make when interacting with a tangible product or space (Steinfield, 2004).

Human movement is multi-faceted; Trew (2001) proposed that it can be viewed from a number of different standpoints:

- Anatomical: describing the structure of the body, the relationship between the various parts and it's potential for movement
- Physiological: concerned with the way in which the systems of the body function and the initiation and control of movement
- Mechanical: involving the force, time and distance relationships in movement
- Psychological: examining the sensations, perceptions and motivations that stimulate movement and the neurological and chemical/hormonal mechanisms which control them
- Sociological: considering the meanings given to various movements in different human settings and the influence of social settings on the movements produced
- Environmental: considering the influence of the environment on the way in which movement occurs.

Human movement is a complex and adaptive skill and therefore it is perhaps not surprising that there are a number of gaps in our knowledge, including a better understanding of what happens when we perform everyday tasks and how aging and impairment impacts on these abilities.

Disabled people learn to adapt and modify their unique abilities to maximise their functionality. Observation of movement reveals the richness and adaptation of disabled people as they seek to master everyday tasks: individuals with spinal cord injuries learn to brace and support limbs to reach outside their normal functional base; people with severe athetoid movements learn to use primitive reflexes to allow them to functionally control a powered wheelchair; people with Duchenne Muscular Dystrophy use 'trick' movements to allow them to raise a spoon of food to their mouths. These examples show how people adapt to their circumstances and function with a degree of independence that belies their structural measurements and to a large degree their functional abilities.

Current design practice is constrained by a lack of accurate data that represents the functionality of people, whose functional abilities is not necessarily captured by the 5th to 95th percentile of human function. This information needs to be presented in a way that can be incorporated into the design process without placing additional burden on current practice, especially where the obligation of total inclusion is still in its infancy or non-existent in terms of product and environmental design.

Clearly there is a need for designers, architects and others involved in shaping the world we live in to have a clearer understanding of this ability and a representation of the richness and diversity of human movement if they are to address the needs of the wider population of people.

JUSTIFICATION

Miller et al (2000) targeted two key issues, namely the lack of designer orientated human modelling software and the lack of ergonomically correct products and environments which are useful to a wide range of people, including elderly and disabled people. This work demonstrated the ability to generate useful Digital Human Models (DHM) visualisations of individual people with disabilities, based on simple measurements of limb segment length and maximum joint angles. This effort to improve and utilise DHM technology for design purposes was important in that it provided a proof of concept demonstration of the potential of the approach and highlighted some of the limitations of current design practice. These models were however based on anthropometric data, which, as stated, has been shown to be limited in its application.

The last few years have seen a dramatic increase in the capabilities of Digital Human Modelling. Parameterised computer simulations have been developed that allow designers and researchers to test the anthropometric fit of a design in virtual space using digital manikins. Although such manikins for able bodied people have been available for some time, Steinfield (2004) declares that accurate and reliable manikins of disabled people are still not widely available.

There is an urgent need for more data on structural and functional abilities of disabled people to be generated before reliable virtual design applications can be implemented. This needs to be initiated by an increased understanding and characterisation of the interaction of people with their environments and products. Conventional anthropometry cannot alone provide this information, even if used to then generate DHM.

Human motion analysis is an incredibly powerful tool that could be used to inform and instruct designers in terms of the functional abilities of both disabled people and older people. It holds the promise of allowing qualitative pre-visualisation analysis of human motion and dynamic simulation of the relationship between humans and the products they utilize and the spaces they inhabit – before the products are manufactured or the environments constructed.

The field of animation has shown the power of this tool in creating lifelike manikins that exhibit all the expression and nuances of human motion. This was recently illustrated by the Imageworks© production 'The Polar Express'©, which used motion capture to create the characters and bring them to life. Using similar technology this research is addressing the lack of ergonomically correct products and environments which are useful to disabled people and older people by creating accurate visualisations of human movement that can interact with virtual environments and products; providing the designer with a unique insight into their needs.

This effort to improve and utilize accurate characterisations of disabled people is important for several key reasons:

1. Disability is caused by many processes and influenced by the unique context in which the individual lives. This includes a wide variety of diseases and injuries, as well as genetic and congenital conditions and an association with the aging process. Other variation is then created by individual lifestyles and circumstances, time factors and others. This seemingly infinite diversity presents designers with major issues in understanding abilities and incorporating the same into the design process and embracing an inclusive approach to design. Traditional sampling strategies have focussed on using a medical model to group people, enlisting pathological definitions to categorise people. While this has proven effective for many projects the focus of this particular work is not related to the specific condition or disability or life cycle stage but is related to the impairment experienced. Therefore this project is using a taxonomy of *abilities*, seeking to group people by what they can do and not what disables or limits them. This subtle shift address the ethos of the project and is instructed by the philosophy of the social model of disability.
2. Miller at al (2002) stated that the design process is, by nature, a time-intensive, non-linear and iterative process, which means that any pressure, such as lack of necessary information, time schedules or financial exigency, will encourage assumptions to be made and misleading stereotypes promoted in order to maintain progress. This in turn can lead to an incomplete or poorly designed product. The nature and extent of inadequately designed resources is experienced daily by every living person and yet human adaptability allows us to master the environments and products used. Disability often limits that ability and leads to impairment and the barriers that currently exist to inclusion. The serious lack of designer-orientated, computer based visualisations and characterisations that can interact in a virtual design environment, continues to perpetuate the creation of products and environments that fail to embrace older people and disabled people as consumers.
3. Assistive technology is often viewed as a 'limited market' (NCDDR, 2001), with very few commercial opportunities. This has led to the relegation of assistive technology and universal products and environments into a category called 'orphan technologies', a term applied because of this perception of limited markets for such products (Miller et al, 2002). This perception is now shifting as a result of changes in the demographics of the population in terms of increasing numbers of elderly people and greater awareness and acceptance of disability as part of the life cycle. This is resulting in much wider recognition of the significant economic opportunities that the market for universally designed products presents.

An interesting illustration of this was highlighted in a recent article from the BBC (Walker, 2004) who detailed how the Ferrari Enzo, a product produced by a company not typically associated with inclusive design, has been redesigned with the needs of the older person in mind. Ferrari recognises that this group in society are increasingly likely to purchase this product and therefore they included such things as widening the seats and raising the door heights. With this increasing awareness there is an urgent need for widely available designer-orientated software that accurately informs and instructs designers about the abilities of disabled people and elderly people so that the proliferation of poorly designed living space and products can be minimised.

PROJECT DEVELOPMENT

This paper reports on an ongoing research project, which is using motion capture technology to create Digital Human Models of people with various abilities. The approach accurately characterises the nuances of functional abilities, for use by designers and clinicians. The proposed activities will lead to improvements in the design and usability of environments and products used by the elderly and people with disabilities. The project will demonstrate the development and use of motion capture technology to characterise people with disabilities and the use of such Digital Human Models to inform the design process.

In general terms the process involves the capture of human movement using an optical measurement hardware and Track Manager system© available from Qualysis. This system uses a 360º array of Motion Capture Unit digital cameras, which emit infrared light. This is reflected off low mass, retro-reflective targets, positioned on the person to capture the position of the targets with high spatial resolution.

Visual feedback is captured by connecting a video camera to the system, presenting synchronised video image along with the acquired data. These two forms of data, motion capture and video can be contrasted and compared to validate the accuracy of the motion capture in representing the functionality of the sample population. Using Visual3D, a software package for rigorous and accurate analysis of 3D motion and the managing and reporting optical 3-D data, the visualisation of the motion data will be presented as mannequins, which will be the form of the Digital Human Models created. Visual3Ds' modelling technique allows for the analysis of mechanical movement, as well as human movement, which will facilitate the inclusion of assistive technologies, such as wheelchairs and other mobility devices.

Preliminary work with the system is creating comparative three-dimensional visualisations that represent the functionality of persons with varying degrees of impairment. These models can be used to illustrate the variability of human movement and accurately illustrate the subtleties of human function. They can also be used to illustrate such factors as the area that a person can reach for an object to be accessible to them or a space within which a person can interact. They can be used to illustrate the comparative space requirements of various users of mobility systems.

A further focus of this work is overcoming the major challenge of grouping impairment, so that the Digital Human Models represent a significant population of individuals, that embraces both disabled people and older people. This is required so designers or clinicians can specify, constrain or widen the characteristics of the people for whom they are designing the product or environment. In addressing this, the diversity of the population needs to be considered.

CONCLUSION

The primary goal of this research project is to demonstrate an approach to the design of products and living spaces that are inclusive of the needs of disabled people, older people and others, challenging misleading stereotypes and embracing the ethos of inclusive design.

Development of the system will seek to integrate Digital Human Models with 3D visualisations of products and living spaces, allowing real-time simulation and interaction; testing a product or environments' performance prior to construction and therefore avoiding the need for expensive 'mock ups'. The project is investigating the effectiveness of computer based systems in assisting designers to interpret the needs and requirements of disabled people and older people. Digital Human Models have the potential to offer designers the opportunity to approach their designs from the viewpoint of a disabled person, or an older person. This could provide a powerful tool in helping designers to make informed decisions about important design issues in relation to older people and disabled people.

REFERENCES

Ashworth, J., Reuban, D., Benton, L., (1994) Functional Profile of healthy older persons. *Age and Aging* 23, 34-39

Blackman, T., Mitchell, L., Burton, E., Jenks, M., Parsons, M., Raman, S., Williams, K. (2003) The Accessibility of Public Spaces for People with dementia: a new priority for the 'open city'. *Disability & Society,* 18: 3, pp. 357-371

Bradtmiller, B, Annis, J. (1997) Anthropometry for persons with disabilities: needs for the twenty-first century. Washington, DC: US Architectural and Transportation Barriers Compliance Board

Clark, M., Czaja, S., Weber, R. (1990) Older Adults and daily living task profiles. *Human Factors* 32 (5), 537-549

Feeny, B. (2000) A study of the difficulties disabled people have when using everyday consumer products. Government Consumer Safety Research: Department of Trade and Industry [online] Available at http://www.dti.gov.uk/homesafetynetwork/pdf/disbled.pdf (accessed January 27, 2005)

Gant, R. (1997) Pedestrianisation and disabled people: a study of personal mobility in Kingston town centre. *Disability and Society*, 12, pp. 723-740

Gordon et al. (1989) 1988 Anthropometric Survey of US Army Personnel: Methods and Summary Statistics. *Technical Report NATICK/TR-89/044*, US Natick Research, Development and Engineering Center, Natick. MA

Great Britain. Parliament (1995) *Disability Discrimination Act*. London. HMSO

Gyi, D.E., Sims R.E, Porter J.M., Marshall R, Case K., (2004) Representing older and disabled people in virtual user trials: data collection methods. *Applied Ergonomics*, 35, pp. 443-451

Miller, J., Jenkins, G., Wang, W., (2000) The Anthropometric Measurement and Modelling Project. *ArchitectureWeek.com*, Nov, pN1.2

Miller, J., Jenkins, G., Wang, W., (2002) The Development of a Functional Visualization System for the Creation of Digital Human Models *Conference Proceedings: SIGGRAPH 2002*, San Antonio, Texas, USA

National Statistics (2002) National Population Projections 2002-based. © Crown Copyright 2004, table 3.2 (Actual and projected population by age, 2002-2031). [online] Available from http://www.ageconcern.co.uk/AgeConcern/information_2662.htm (accessed March 7, 2005)

Neufert, E. (1980) *Architects Data.* (2nd ed) New York: Halsted Press

NCDDR (2001) *NIDRR's Long Range Plan – Technology for Access and Function Research*, Section Two: Chapter 5: Technology for access and function. [online] Available from http://www.ncddr.org/rpp/techaf/Irp_ov.html (accessed December 2001)

Oliver, M. (1990) *The Politics of Disablement*. Basingstoke: Macmillan

Paquet, V. (2004) Preface. *International Journal of Industrial Ergonomics*, 33, pp. 177-180

Stait, R., Stone, J., Savil, T., (2000) A survey of occupied wheelchairs to determine overall dimensions and weight: 1999 survey. *TRL Report 470* prepared for Mobility and Inclusion Unit, Department of the Environment, Transport and the Regions, UK.

Steinfield, E. (2004) Modelling spatial interaction through full-scale modelling. *International Journal of Industrial Ergonomics*, 33, pp. 265-278

Trew, M., Everett, T. (2001) *Human Movement: An introductory text*. 4th edition. London Churchill Livingstone.

US Government (1996) *Americans with Disabilities Act*. Washington DC [online] Available from http://www.usdoj.gov/crt/ada/statute.html (accessed March 7, 2005)

Walker (2004) Live fast, die old. *BBC News Online Magazine* [online]. Available from: http://news.bbc.co.uk/go/pr/fr/-/1/hi/magazine/3659996.stm (accessed December 10, 2004).