Supporting an inclusive, sustainable approach to design and manufacture

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SUPPORTING AN INCLUSIVE, SUSTAINABLE APPROACH TO DESIGN AND MANUFACTURE


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Abstract. Taking a more inclusive and accessible approach to the design of products, services and systems is supported with a proven business model. Due to the increasing age of global populations and the prevalence of people with a disability, there is a significant market to be addressed through more inclusive design. Taking an inclusive approach can then act as a driver for more sustainable product development ensuring that products meet the needs of the broadest range of users possible and are sufficiently flexible to meet the changing demands of users as they age. This paper reports on research done in order to address shortcomings in the tools available to designers looking to take an inclusive approach and the availability of data to support such tools. In particular the paper introduces a digital human modelling tool called HADRIAN designed to allow the evaluation of designs within a CAD environment that consider the abilities of a very broad range of users. However, design is one element within the realisation of products. This paper explores also explores the use of HADRIAN beyond its initial design-led remit, into the implications for the manufacture of these inclusive products as part of a broader view of sustainable manufacturing practice.
1 INTRODUCTION

Sustainable development is typically identified as consisting of three main elements: economy, community (or society) and ecology (or environment). Depending on the context in which they are used, the literature shows subtle changes to these elements or their emphasis. However, a constant in the view of sustainability is the interconnections and the supporting structure of each element with each other [1]. One of the components of this view regards technology and this encompasses both design and manufacturing. McDonough and Braungart [2] put design at the heart of achieving sustainability and identify six design criteria including: cost, functionality and aesthetics. To these more traditional design and manufacturing criteria they also add: ecological intelligence; socially just manufacture, use and disposal; and finally, guilt free fun. Clearly there is some interpretation of these criteria and the additional three are potentially not as clear cut as, for example, cost. However, what these criteria do provide is a framework for design and manufacture that addresses the need for good products, that are sustainable throughout their lifecycle, and this cannot be achieved without sustainable approaches to both design and manufacturing.

In considering sustainable approaches to design and manufacture it is necessary to consider the human element. A review of the sustainable manufacturing literature shows that the human aspect of sustainability is often overlooked, with sustainable manufacturing being fundamentally focused on the ecological concerns [3][4]. In his guest column for Clean Technologies and Environmental Policy, Vijay Srinivasan, the Chief of the Manufacturing Systems Integration Division of the National Institute of Standards and Technology in the US (NIST), supports the view that sustainability is a key driver of innovation and refers to the NIST workshop on Sustainability Manufacturing: Metrics, Standards and Infrastructure [5]. Yet, whilst the workshop identified “top attributes” under the headings of Critical Factors Driving Sustainable Manufacturing, and Decision Support Systems for Sustainable Manufacturing, the outcomes take very much an eco-centric view [6]. The emphasis is quite clearly on ecological impact and the ability to analyse and measure that impact. Where the literature does refer to the human element it is considered largely from a generic societal, or directly end-user / customer perspective. Yet in order to achieve fully sustainable manufacturing, the people working in manufacturing must form a central part of any system wide view.

One of the important trends that has a direct bearing on sustainability within design, manufacturing and beyond is that of ageing populations around the world. Currently 10% of people are over 60, and by 2050 it is predicted this will be 20%. In addition, there is a shift in the proportions within the population of older people with those who are 80 years and over growing from 13% currently to 20% in the next 40 years [7]. In the UK, currently 16% of the population are over 65 with a predicted rise to 23% by 2034 [8]. To accompany the rise in population age, there is also a decrease in the number of younger people. The impact of these changes on the workforce is significant and this has been recognised by Governments attempting to address issues of retirement age and pensions to ensure that society can afford to grow older. Jahani Ilmarinen in his article on the ageing workforce identifies four factors in the solution to this ageing challenge, the third of these concerns “better age-adjusted and

flexible working” [9]. He also discusses the promotion of “work ability”. Work ability focuses on the balance between human resources and working conditions, including not only the ability of workers to do work, but also factors such as conserving the knowledge of older workers [10].

The ageing population is now increasingly recognised and strategically addressed within the design community as part of a promotion of inclusive or universal design principles [11]. However, the manufacturing industry still has yet to fully address the ageing population issue with many companies (less than 20% in many EU countries) failing to implement any strategy to actively recruit or retain workers over 50 [12]. Whilst the issue of an ageing population is seemingly well recognised, addressing it is far from straightforward.

This paper takes a human perspective on sustainability and presents research performed as part of the Sustainable Urban Environment Programme, funded by the Engineering and Physical Sciences Council (EPSRC) in the UK into supporting designers in their efforts to tackle inclusive, accessible and sustainable approaches to design. The outcomes of this research include an inclusive design tool called HADRIAN, the characteristics of the tool are explored and also recent developments to evaluate the abilities of the tool within the context of manufacturing are discussed.

2 AUNT-SUE

Accessibility and User Needs in Transport for Sustainable Urban Environments (AUNT-SUE) is a consortium of UK academic institutions including London Metropolitan University, University College London, and Loughborough University, together with local councils and other public and private bodies such as Camden Council, Hertfordshire Council, and the RNIB. The consortium’s aim is to produce methodologies for sustainable policies and practices that will deliver effective socially inclusive design and operation in the transport realm.

The social, ethical, legislative and business cases for products, services and environments that are accessible and inclusive are well established. Yet, ‘good design’ is perhaps not as common as it might be, with products still being designed without appropriate attention being paid to the needs of all users. However, the complexity of design should not be underestimated and often design and manufacturing organisations are managing a complex array of stakeholder requirements. Often requirements are conflicting and demand different directions for the design. One of the key deliverables of AUNT-SUE was a ‘toolkit’ that recognised the need to support the ‘design practitioners’ in ways to identify, understand and accommodate the needs, desires and aspirations of as many users as is possible. This toolkit addresses transport needs from the macro scale, through policy decision support tools, through to micro level decisions on the design of a part of the transport infrastructure such as a vehicle, ticket machine or access barrier.

Loughborough University’s role in the research has led to the development of a number of tools centred on providing a better understanding of the variability in people, but also in fostering empathy with those who are being designed for. The research has identified two main issues. Designing to be accessible and inclusive can be difficult when access to data on people is limited. Also, even with access to appropriate data, existing data tools are often not in a format or language that designers can access, relate to, or apply easily.
3 DATA NEEDS

For designers wishing to ensure their products meet the needs of an ageing population, ergonomics data on the size, shape and capability of people plays a significant role. An appreciation of these data is fundamental if a design is to be suitable to address the variations of people within a population. However, most data sources available to the designer have issues that limit their applicability. One of the fundamental issues regards how representative the data are of the population they are meant to represent. Three factors in particular are of concern including the age of the data (when it was collected), the age of the people from which data was collected, and the characteristics of the data sample. Often anthropometric population data is more than 20 years old and is collected for age groups between 18 and 65, and as discussed earlier the population has aged (and changed in size and shape) significantly over this time. In addition, population data is almost always taken from people without a disability. Data that is collected from people with an impairment is often of very limited sample size and contains a limited range of measures. Designing products, environments, and workplaces using this data will inevitably lead to a poor experience for users, musculoskeletal problems for workers, or even the inability to perform a work related task at all.

For more recent databases such as SizeUK [13] and CAESAR [14] the data is recent and comprehensive. Their age, number of people, and sampling strategies make them much more representative of their respective populations. However, they are relatively expensive and beyond the reach of many designers.

The final concern is that data are largely unspecific to a particular task or environment. Yet, the design task they are being applied to is likely to be very specific. One simple illustration of this is that data are often collected without clothing, yet there are few design situations where a design would need to accommodate unclothed users. Factoring in standard clothing allowances makes the task much more complex and requires a high level of experience and expertise; to allow for heavy, bulky, and restrictive safety equipment is more complex again. In an inclusive design context the task and environment may be relatively common, cooking a meal in a kitchen or getting a ticket from a ticket machine on a train platform. However, older and disabled people often employ coping strategies that mitigate against any impairment they may have. These coping strategies are rarely documented and add yet another layer of complexity to the designer wishing to design inclusively.

4 DIGITAL HUMAN MODELLING AND HADRIAN

One expedient way of evaluating the suitability of a design or manufacturing environment is through the use of virtual evaluations using digital human models (DHM) together with a CAD model of the product, environment, or workplace. The use of a DHM system allows designs to be evaluated with a range of potential users to explore issues of fit, reach and vision at an early stage in design or planning so that users can be fully accommodated prior to user testing with full size prototypes. In this way problems can be addressed early on, when changes are much easier and less costly to implement.

To address the issues highlighted above this research led to the development of an inclusive design tool called HADRIAN (Human Anthropometric Data Requirements and Analysis).
HADRIAN is firstly a software database of 103 people, with an age range of 18-89 years, and including 59 people with a broad range and severity of disability [15] [16]. The data in the database are presented in a highly visual manner and comprise a broad range of body size, shape, joint range of motion, and task based capability. In addition to physical information, the database includes a wide range of data about behaviour, and lifestyle, both at home and out and about. The data can then be explored in a number of ways depending on the needs of the user, including disability and demographics, anthropometry, behaviour and emotion, transport use and so on. Presenting the data in this manner and supporting the designer in exploration of individuals within the database provides empathy with the people being designed for. Practitioners are presented with a data-driven description of the people in the database, are able to watch video clips of those people performing tasks to understand their abilities but also to understand how the tasks are performed and the strategies employed, and are able to watch selected clips from interviews where the people in the database relate experiences of travel and modes of transport.

At present an online resource (scheduled to be available later in 2011) is being developed that will enable easy access to the HADRIAN data [17].

Figure 1: An example of HADRIAN data.

In addition to fostering empathy the data also support design decision making. HADRIAN is a 3D human modelling and task analysis system capable of simulating discrete physical interactions that are based on the complex limitations of real people rather than generic population data [18]. HADRIAN is supported by the SAMMIE DHM system and is used to perform an analysis of a design by firstly defining a task. The task is broken down into various elements such as look at the screen, reach to the card slot etc.
HADRIAN will then run the analysis building the people in the database together with their correct size, shape, and capabilities and perform an automated analysis that attempts to perform the task as described. When the analysis is complete the system then provides details of who experienced difficulties in performing that task and why. The practitioner can then explore the individuals who experienced problems, understand why these problems occurred and experiment with solutions by modifying the computer model of the design and re-running the analysis in HADRIAN.

5 A MANUFACTURING PERSPECTIVE

DHM systems have been used in manufacturing operations for many years, particularly in evaluating assembly operations, as part of an increasing desire for virtual manufacturing and simulation tools [19]. The limitations discussed in this paper regarding the applicability of data to drive evaluations for design is equally true for manufacturing. If the efficacy of an assembly task is established using DHM with virtual humans based upon unrepresentative data, the task design and supporting equipment will be unsuitable and it is unlikely that this will be discovered until a user trial is performed, if at all. With the additional influence of the ageing population, and ageing workforce, it is likely that this will become an increasingly likely result and thus diminish the potential benefits of using DHM systems in this manner. However, even without the use of DHM within manufacturing operations, design engineers and planners are likely to be basing their decisions on the experience of a much younger target population or an unrepresentative view of the abilities of older people [20].

Thus it is proposed that the approach taken to supporting designers in inclusive design using HADRIAN is equally applicable to the workplace and in particular manufacturing assembly tasks. Through the provision of more applicable and accessible data, together with a means to exploit that data for virtual task-based evaluations of a proposed workplace and task design, it is believed that efforts in addressing work ability can be better supported and ultimately help to address the need for more sustainable manufacturing systems.
Recently research has begun to evaluate the efficacy of the HADRIAN tool in manufacturing evaluations. At present this research has addressed the capability of older workers, in particular joint range of motion and the representativeness of the HADRIAN database. The representativeness of the HADRIAN database is critical to the validity of any evaluations performed, but it is also important in allowing users of the tool to interpret the results more generally. As discussed, the database contains data on 103 people. Whilst these 103 people cover the spectrum of size, shape and ability it is important to be able to correlate the exclusion of a single person in the database with a sub-set of the population. For example HADRIAN might report that participant 77 is excluded from performing an assembly task that requires fine manipulation of a particular component. On further investigation this failure is due to the individual's arthritis. For the designer or planner it would be useful to be able to know how many people in the working population also have arthritis of a similar severity to this participant. Access to this information would then provide a context to any subsequent decisions to change the task, workstation, or even the design of the product, to ensure that the assembly operation could always be completed regardless of the composition of the workforce.

6 CONCLUSION

Taking a more inclusive and accessible approach to the design of products, services and systems has become increasingly recognised within the design realm. Due to the demographic change within global populations there is a significant opportunity but also challenge to address the ageing consumer and worker. However, design is only one element within the realisation of products. There is also a need for a sustainable and intelligent approach to manufacturing that can complement inclusive design and also address a more inclusive approach to manufacturing operations. Research performed at Loughborough University has attempted to address shortcomings in the tools available to designers looking to take an inclusive approach and the availability of data to support such tools. This research has led to the development of an inclusive design tool called HADRIAN, created to allow the evaluation of designs within a CAD environment that consider the abilities of a very broad range of users embodied as a virtual user group of over 100 people. These evaluations, if performed early in the development process, can then be used to ensure that the design direction is suitably accommodating. HADRIAN is now being explored beyond its initial design-led remit, into the implications for manufacturing.

REFERENCES


