Comfort equals productivity

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Comfort equals productivity

To satisfy market demands, vehicle designer must ensure that the capabilities, needs and characteristics of end users have a major influence upon design decisions. Ergonomics input is therefore essential throughout the design process, but it is most important at the concept and early development stages. Basic ergonomic criteria need to be satisfied very early in the design because often there is only limited scope for design modification later on without considerable financial and time penalties.

While detailed ergonomic design of controls, consoles and displays has become more common in the early stages, assessment of the overall package still tends to be conducted nearer the end of the process. Ergonomics assessments have traditionally relied upon user trials assessments of physical models or mock-ups. These take time to construct and can be difficult to modify, which means they are usually developed once the design has progressed some considerable way. However, there is increasing pressure to minimise design timescales and to meet this requirement, more and more often, vehicles progress from concept design through to production using modern CAD/CAM systems without full-size physical models or mock-ups being used to perform any necessary evaluations. Since most CAD/CAM systems provide little or no information concerning the capabilities and needs of the end user, there is a considerable danger that design decisions may only consider the engineering, styling, legislative and financial constraints while ergonomics issues remain comparatively

Computer aided human modelling systems can be used at the earliest stages of a design process to assess ergonomics where it can provide most benefit and while there is still plenty of time for modification.

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Figure 1: A 95th percentile US male operator in a concept excavator cab working in forward mode
unsupervised until the design is more or less completed, by which time it is too late.

Computer-aided human modelling systems have evolved to address this issue, and provide powerful support tools for the earlier stages of the design process by enabling the prediction of the percentage of future users who are likely to experience problems with clearances, vision and reaching, or who will be forced to adopt unnatural or damaging postures. The graphical representation of ergonomic problems in such systems supports efficient communications and solution-oriented action within the design team. In addition, the fact that these systems allow rapid and iterative modifications to concept designs enables the whole design team to contribute to and take ownership of design solutions. The use of human modelling systems enables a more proactive approach to ergonomics design and allows the emphasis of user trials to focus on the "fine tuning" of a design as opposed to basic assessment of fit, reach, vision and postural comfort.

SAMMIE (System for Analysing Man Machine Interaction Evaluation) is a human modelling computer-aided ergonomics design system, conceived in the late 1980s and used as a consultancy tool on a daily basis since 1978.

The system was developed by SAMMIE CAD Limited, an Ergonomics Society Registered ergonomics design consultancy. This article describes the functionality of the system and how it helps to promote user-oriented engineering design, using examples from recent consultancy projects.

**System functionality**

SAMMIE is a predictive tool that enables the assessment of postural constraints placed upon individuals while interacting with the designed physical environment. It is a general-purpose tool and not specific to, although commonly used for, vehicle evaluations.

There are five basic functions, with the first being 3D modelling of people of the required sex, age, nationality and occupational groups so that the full range of potential users can be represented, achieved using published anthropometric data, where available, for the relevant user population. The system provides considerable flexibility of control over the human models allowing size and shape selection for 1st to 99th percentile for whole-body or body segment dimensions.

Another function of the tool is a database of comfort angle ranges for major body joints, together with joint movement limits that constrain the human model's movement to be representative of real human capabilities. It also offers the ability to model elements of the proposed workstation in 3D together with the ability to simulate model functionality, such as ranges of adjustment, control operation ranges, and the structural and functional relationships between model elements. This working model is essential because it needs to interact with the design to enable the physical characteristics of the man-machine interface to be evaluated. Since human modelling systems are most effectively used in the concept stage of design, they need a basic model building capability because they should be used prior to the development of detailed CAD models on the main engineering system.

Another function offered is that of being able to assess the kinematic interaction between the human models and the workplace, specifically in terms of fit, reach, vision and detection of collisions. The assessment focuses on whether or not the people modelled can work efficiently within the workplace and adopt comfortable postures (i.e., within the ranges of acceptable joint angles). Additionally, lifting and handling risk evaluation is supported by facilities for making NIOSH lifting equations and RULA or OWAS postural assessments, as well as limited spinal loading analysis.

Lastly, the tool offers the ability to make iterative modifications to the design to achieve optimum compromises.

**Design benefits**

SAMMIE CAD Limited has completed in excess of 170 commercial projects for over 80 national and international clients. The company begins any consultancy project by asking a number of basic but essential questions. Firstly, it determines who the intended user of a design will be—something that is often not at all clear in the client's mind. This forces the client to make important decisions about the acceptable accommodation range (e.g. 95th to 95th percentile or wider) and the user population at the earliest stage of design.

The next step is to help the client establish a clear definition of all the tasks that the user is required to perform so that they can be simulated in the evaluation. This helps establish a specification for the workstation and associated equipment elements and to set task priorities. This process often identifies conflicts between various task functions.

For example, SAMMIE CAD was recently involved in the design of an excavator where the user was required to operate the vehicle facing both forward and backward. While the proposed layout of controls and range of seat adjustment accommodated the majority of users in comfortable postures in forward mode.
(Figure 1), rear-facing operation would require a highly twisted spine posture (Figure 2). Also, smaller users (particularly females) would not be able to make effective reaches to the controls. The two main task requirements for vehicle operation clearly conflicted and little thought had been given to the postural requirements of rear-facing operations. Maintenance of the twisted posture for any length of time or frequent repetitions of it would be likely to rapidly lead to discomfort and possibly injury in the long term. SAMMIE was able to clearly demonstrate the problem to the design team in an unambiguous visual manner. Using the system's editing facilities it was possible to investigate and demonstrate the relative benefits of various design solutions, including a revolving seat with additional rear-facing controls or the use of rear-facing remote CCTV cameras with monitors integrated into the cab.

During the task simulation the assessments of fit, reach, vision and posture are conducted simultaneously to fully determine the feasibility and suitability of the required operations. An evaluation of a proposed fork lift design clearly demonstrated the problems that operators would experience when stacking a load onto shelving. Figure 3 shows the fork lift driver adopting a very poor posture as he leans out to get a good view of the edge of the load, while also reaching to and operating various controls. The driver's field of view is demonstrated in Figure 4. The SAMMIE evaluation showed that the driver would have to continually adopt poor postures in order to compensate for the fact that his visual field was so poor. The preferred solution to the problem was determined to be the provision of CCTV cameras mounted on the fork assembly giving the driver remote vision of their load's extremities and allowing them to perform loading tasks while maintaining a stable and comfortable driving posture.

Determination of the users, what tasks they will perform and under what conditions they are expected to work is important in that it forces the client to make decisions that affect the usability of a vehicle at the earliest possible stages of design, thereby ensuring the early input of ergonomics expertise. It is then possible to construct appropriate human models and position them in 'working' postures with only the simplest of geometric models. Areas of common reach and vision for various sized human models can be identified for the placement of primary controls and displays before these items have been designed in detail. The minimum volume of space required by the users to adopt their various task postures is easily observed at the earliest stages of design, and this provides the possibility of ensuring sufficient clearances are provided as the design progresses. Such information and feedback can be provided throughout the development process, allowing ergonomic issues to be considered proactively. This simultaneous consideration of people and engineering issues promotes the identification of optimum compromises, which are essential for a successful design.

One of the major advantages of using SAMMIE is that it enables significant time savings to be made. A recent project conducted for the UK Department of the Environment, Transport and the Regions with ICE Ergonomics Limited, involving the quantification of vision from large vehicles, illustrates this. SAMMIE used a coordinate measuring arm to digitise the cabs of nine test vehicles, from which models were built in a matter of days. Direct and indirect fields of view from windows, mirrors and CCTV cameras were then determined - the use of SAMMIE enabled the problems associated with the field of view from large vehicles to be determined and quantified quickly. Importantly, the system allowed rapid modifications to vehicle glazing, structure and mirror systems and the addition of CCTV s enabling rapid investigation of alternative methods for improving the field of view, which would have been very costly and time-consuming had this been done using real vehicles.

SAMMIE can also be beneficial to the design process by providing rapid and timely iteration so that ergonomics input can keep pace with rapidly changing design ideas and requirements.

In addition to reduced timescale and rapid iterative design, the software offers much improved communication within the design team. As the system is logical and objective in its approach, all of the stakeholders in a project can easily visualise any design problems identified, question any assumptions made and be directly involved in the investigation of alternatives.

Validity

The geometric evaluations of fit, reach and vision have been shown to be acceptably accurate by all of SAMMIE CAD's industrial projects which have successfully undergone the transition from computer based prototype to full-size mock-up and then to manufacture.

However, whenever possible the company aims to combine the use of SAMMIE with more traditional ergonomics methods. For example, SAMMIE was involved in the development of the Fiat Punto, voted European Car of the year 1995. The system was used to model the prototype Punto from engineering drawings in 1992 to help ensure high levels of driver accommodation for a variety of nationalities. Subsequently, the focus shifted to the design of the seats.
with this work being conducted by the Vehicle Ergonomics Group based in the Department of Design and Technology at Loughborough University, UK. Camouflaged prototype Puntos and competitor cars were assessed in terms of driving discomfort during a 60 mile road trial. This analysis led to the subsequent redesign of the car's seats, and a second set of road trials demonstrated that these changes successfully ensured that the Punto had class-leading levels of accommodation and comfort. It was essential that the fine-tuning of the seat design was based upon a sound driving package, as this is of paramount importance in the avoidance of driver discomfort.

SAMMIE CAD has always advocated that human modelling systems should not entirely replace user trials with full-size mock-ups unless the design or design modifications are so simple as not to warrant concern. In depth user trials can reveal problems with many more issues, including long-term discomfort, effects of fatigue, negative transfer of training, error rate, heat and noise stress, performance and even the acceptance of the product. Many designers, engineers and ergonomists are expertly waiting for the full-swing, all-dancing human modelling system to appear. The likelihood of such a system being developed in the near or distant future seems remote. However, the use of systems such as SAMMIE should help to ensure accommodation of the full range of users by design from the very outset, with user trial testing serving to prove the design and as a means of considering other task-related factors such as environmental stresses, information processing, lighting, vibration effects, etc.

SAMMIE uses CAD techniques both as a tool for ergonomics analysis and as a communications medium. The work is conducted on screen and requires a high degree of interaction between design team members. The working computer models are generally very simple since they are built from the limited information available before detailed engineering development has taken place. Simple models allow the design team to focus on the important ergonomics issues. However, at the completion of the work, nearly as much time again is often spent constructing a more detailed and aesthetically pleasing model, since this helps to impress the client and impart a greater sense of validity. We find it considerably easier to communicate using a 3D computer model of an ergonomics design rather than the traditional report listing recommendations. CAD tools such as SAMMIE encourage creative solutions to functional problems by allowing the design team to quickly explore a variety of options against design constraints.

It is the company’s belief that the use of human modelling systems such as SAMMIE promotes the early input of ergonomics into a design where it can be most beneficial. It enables ergonomic evaluation at the concept stages and in so doing offers savings in time and cost, provides and promotes rapid iterative solution-oriented problem solving, improves design team communications and promotes proactive ergonomics input. This minimises the likelihood of expensive design modifications being necessary later in the design process, thereby offering cost-effective ergonomics and a design process that results in an effective and user-friendly vehicle.

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