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Digital Human Modeling Research and Development User Needs Panel

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ABSTRACT

This panel provided a forum for discussion of future research and development desired by users and potential users of DHM technologies. The discussion was based on the experiences of users from various sectors and industries. Panelists provided written statements and delivered short presentations prior to opening the session to audience discussion. The panel was designed to inform and drive research and development plans to fill these needs.

INTRODUCTION

Human performance researchers and developers of human modeling tools focus their efforts on addressing perceived needs of the users of their products. This is a challenging task. Some organizations have mechanisms established to ensure that the actual needs are addressed. In the commercial sector, marketing departments often serve as the primary means of determining what customers want in a product's human interfaces, or production engineers, managers and plant medical departments define what is needed in the work environment. These mechanisms are however, imperfect, as described in DHM case studies (Chaffin, 2001).

PURPOSE

The purpose of this panel is to provide a forum for discussion of future research and development desired by users and potential users of DHM technologies. The discussion will be based on the experiences of users and will provide input to research and development plans to fill these needs.

STRUCTURE

The panel consisted of an introduction by the panel organizer, panelist statements, audience discussion, and summary by the panel organizer. Six customer oriented panelists covering:

- Commercial vehicle design communities (land and air).
- Department of Defense concept development, testing and evaluation
- Manufacturing sector
- Educational and academic research sectors
- Analysis tool developers

Each panelist was asked to deliver a 5 minute statement to address some or all of the following questions.

1. What is necessary for your organization to invest in a DHM analysis tool?

2. What is the expected background of potential users of the tool; such as how much CAD, ergonomics, product/process design expertise are they likely to have?

3. What is a reasonable amount of turnaround time allowed per project?

4. What type of validation evidence is really required? Are you satisfied with "experts" saying that the tool is valid, or do you want to know that there is empirical evidence that the tool is accurate in representing various population groups and human attributes? What degree of accuracy or tolerance is required in many projects?

5. What analytical capabilities are not provided by existing tools? What population attributes and limitations are not currently addressed to your satisfaction in existing tools?

6. What foundational data or research is lacking to develop these missing human simulation requirements?

7. Are there regulatory requirements that affect how you chose a tool or how you apply a tool?

8. What determines the ultimate success of the tool?

The panelists were also asked to provide a written abstract of the main points of their oral statement.

PANELIST STATEMENTS

Ernst Assmann, Ph.D.
Ergonomist
BMW Group

In the German automotive industry digital human models are mainly used in the design of new cars, or more explicitly in the packaging of the interior and in ergonomic assessment of car concepts. Since cars have been built for more than 100 years, every company has methods to do these tasks without DHM. Every new tool therefore has to prove its superiority in saving time and/or money and increasing quality. As hardware tests will always be conducted toward the end of the development process, the validity of the virtual analysis can be quantified. When a new tool is introduced, it will be tested by comparing its results with those found by traditional methods. Besides the reduced need for hardware mock-ups and prototypes, the main advantage in using virtual tools in the development of cars seems to be the ability to test a larger range of virtual subjects. Therefore, the expectations for the validity of the final concept and consequently the accuracy of the tool are considerably high. Although the position of a real customer in a car is almost impossible to predict because it is not only determined by his or her physical properties but also by his or her individual preferences, the expected accuracy is in the range of a few millimeters.

Today the most probable position of subjects in a car together with their reach envelope and view are standard tests. Naturally these analyses can also be used for the layout of the seat and steering wheel travel. The position of the seatbelt and the space necessary for actuating controls can also be tested. For these tests the anthropometric properties of the DHM and thus the validity of the underlying data base is of great importance as well as a reliable tool to predict the posture.

A model of the dynamic movement of the whole body is necessary in order to analyze ingress and egress of a car. Several studies have been carried out and reported at past SAE digital human modeling conferences that lead in this direction. As seat manufacturers increasingly model their seats mathematically, the contact between human being and seat can be described more precisely. It remains to be seen if these models will be suitable to replace the existing posture models.

Many digital human models provide a comfort rating for the evaluation of postures. An absolute scale would be desirable together with ratings and recommendations for health and safety issues. The aging population is of great concern for all manufacturers. DHM's should include the influence of age on stature and posture. Finally, extending view analysis towards readability would be a first step into a cognitive assessment.

Rush Green
Human Factors Design Specialist
Boeing Commercial Airplanes

Human modeling at Boeing has evolved greatly in both sophistication and application during a history that goes back nearly 40 years. When first introduced, human models were used by a small group of experts, primarily to evaluate pilots' reach and vision. With the advent of Computer Aided Design (CAD), it became easier, and necessary, to use human models to evaluate other areas of the airplane design.

In Boeing Commercial Airplanes (BCA), human modeling began to grow during the design of the 777. At this time, in the late 1980s, there were no commercially available human models that met BCA's requirements.

So BCA developed its own human model that was resident in the CATIA CAD system. The benefits of the human model became apparent, and use of human models slowly increased in both areas of application and numbers of users.

Now, the next generation of anthropometric models is used by a large number of BCA engineers and designers to evaluate human interaction for pilots, passengers, flight attendants, ground service crew, and the mechanics who build and service Boeing airplanes. And now that it is easy to perform basic analysis of access, reach and vision, greater demands and expectations are being placed on these models. With implementation on the 787 airplane program, several new requirements have emerged:

- Dynamic strength analysis – Static strength models provide rough guidelines for tasks requiring high forces. Often we are concerned with the perceived difficulty or comfort of a movement.

- Integration of CAESAR anthropometric data – The CAESAR data is not easy to integrate with models based on traditional anthropometric measuring methods.

- Population accommodation analysis – For body size, strength capability, vision, or other attributes. An easy way to determine what percentage of a population is included or excluded by a given design.

- Ties to Discrete Event Modeling – For individuals, a simple text based way to create task simulations. For groups of people, a way to model manufacturing flow, or passenger ingress and egress.

- Predictive posturing tool – Given a set of constraints such as support points and task parameters, the manikin assumes the most advantageous, or perhaps most comfortable posture.

- High fidelity clothing modeling – This can provide better fidelity on accessibility and postural analysis, as well as provide more realism for pictorial presentations.

Matthew P. Reed, Ph.D.
Associate Research Scientist
University of Michigan

Colleges and universities use DHM software for ergonomics education and research. The currently available human modeling tools are useful in both areas, but improvements in the software and in the relationship between the software developers and academia would improve the preparedness of graduates for professional work in ergonomics and facilitate the development of new models for ergonomic assessment. In the U.S., few undergraduate ergonomics programs include training in the use of human figure models, even as the professional practice of ergonomics increasingly relies on these tools. Although one impediment is the lack of familiarity among the faculty with the software, the complexity of the user interfaces and lack of high-level control of posture and motion limit the use of the tools. Instructors are also concerned with the accuracy of analyses, because rigorous, independent assessments of validity are not available for the commercial DHM software applications.

In ergonomics research, DHM software currently provides a valuable visualization tool, but should provide much more. The integration with motion capture technology has improved in recent years. Yet, few ergonomics and biomechanics labs use commercial ergonomics software as their primary means of gathering and analyzing posture and motion data because the needed functionality is not available. This separates the development of new ergonomics analysis tools from their subsequent application context, resulting in most new ergonomics findings and models being formulated in ways that make them difficult to implement in DHM software.

Ergonomics researchers need software with a robust biomechanical foundation, including thorough integration with motion capture systems, accurate and complete skeletal models, configurable body segment parameters, and integrated forward and inverse dynamics capability. The functionality should be accessible through a programming interface that is easy to use, provides complete access to the DHM features (e.g., manipulating the figure and other objects in the scene), and allows external functions to be executed in real time. This capability will allow university researchers to lead the way in improving current model functionality, such as integrating cognitive models into movement simulations.

Ulrich Raschke, Ph.D.
Program Manager, Human Simulation Technologies
UGS

Human models are being used to reduce the ergonomics issues associated with design, assembly verification and serviceability of products, saving cost and bringing products to market more quickly. Development of human modeling technology to answer the wide range of questions posed by the potential user community is challenging, as the same presentation of features does not serve everyone's needs. In the past, many of the high-end human modeling tools were targeted at the ergonomics experts within commercial and research communities. An in-depth toolbox of analysis capability, accessed through a flexible user interface, met this objective. However, with the continuing transition to digital manufacturing, not only human factors specialists need to be involved in the evaluation of ergonomics issues, instead, those with little human factors background now are responsible for first pass ergonomic evaluation. This requires a different presentation of functionality. Paradoxically, it requires a greater sophistication of the software to restrict misuse and present complex analysis capability through a simplified easy-to-use interface. Furthermore, the functionality must be integrated into the process tools, including product design, process layout, visualization and collaboration. The integration allows companies to realize the greatest amount of value for their human modeling technology investment, and model publishers are investing heavily to integrate the existing human modeling functionality within CAD, Simulation and Product Data Management frameworks.

With the accessibility to human models, questions are being asked by users that are increasingly difficult to answer with the currently available human performance models. For example; what is the best exposure balance to tasks requiring different levels of physical exertion to avoid fatigue over an 8 hour shift? What strength capability degradation is to be expected with an aging workforce? What is the force exertion limit for a particular hand or finger assembly operation, such as inserting thumb press connectors? What variation in postures can be expected for a given task, and what is the associated likelihood of injury? What is the impact of clothing on joint mobility, and what is the impact of the clothing bulk on accommodation requirements?

Human model providers largely must rely on the academic community to provide data and models for these important questions. The model publishers themselves are challenged with developing simple interfaces and tight integrations with product lifecycle engineering software to facilitate rapid determination of ergonomics issues for the expanding user communities.

Jean-Pierre Verriest
Senior scientist, head of Biomechanics and Human Modeling laboratory
National Research Institute for Transportation and Safety (INRETS/UCBL)

As part of a research institute (INRETS), the LBMH laboratory is involved in projects aimed at facilitating the integration of users' needs in the design of products, especially in terms of transportation safety and comfort. Its contribution consists of collecting data on human performance and developing simulation algorithms to be used by DHM software editors and industrial end users of this technology. A proprietary test platform (MAN3D) enables evaluation of new simulation modules.

Satisfying users' needs in the DHM area is really challenging. Apart from regular ergonomic requirements for software, DHM tool development faces some important problems such as:

1) Usability and required user expertise

2) Relevance to the problem to be solved (generic/specific)

3) Tool personalization

4) Advanced human functions

5) Ergonomic criteria

DHM tools are complex and using them requires good expertise in different fields. It is necessary to know ergonomics but also to have CAD skills and to have a detailed knowledge of the various features of the product being designed/evaluated. Users satisfying all these requirements are not so common and there is no one typical user but sometimes a wide spectrum of users with different backgrounds involved in a cooperative effort.

Should the tool be generic or specific? Indeed, while the human operator does not fundamentally change with the product, the expected tool functionalities can be very different from one technical area to another. It is often necessary to personalize the tool according to trade-specific needs.

There is a set of minimal basic human function features that a DHM tool must exhibit (anthropometry, kinematic model, posture manipulation, etc), but numerous other features are required to properly and realistically simulate human activity. These include load exertion capacity, body balance control, simple but realistic movement and displacement functions, environment interactions, object grasping, carrying and manipulation, complex movements simulation.

For ergonomic evaluation of job/activity situations, it must be possible to create scalable activity scenarios based on linkable generic actions, each providing an ergonomic score. Such scenarios can be used to perform a stepwise exploration of a solution space involving a population and a work situation respectively defined by a set of individual parameters and a set of design parameters, in order to compare situations and find optimal combinations.

Some of these aspects were addressed in two simple situations on which LBMH has been working recently. They are grasping and buckling a safety belt in a car (movement simulation for different interior design) and simply removing a screw with a wrench on an assembly (i.e. sequence of operations with object interactions). These situations, considered as very simple by the end users, required specific research actions with human subjects to collect data and develop submodels (e.g.

hand kinematic model, movement parameterization, discomfort scores, etc). This cannot be repeated endlessly. For research teams, it is important to turn knowledge gathered on specific situations into generic knowledge adaptable to any work/product situation.

John F. Lockett
Acting Chief, Integration Methods Branch
Human Research and Engineering Directorate
US Army Research Laboratory

Research and development (R&D) in digital human models must consider that pressure to speed deployment of new technologies to military systems has increased at the same time that the complexity of those systems and organizational structures is increasing. Modeling and simulation can help to address these concerns if barriers to valid use of digital human models (DHMs) are addressed and if the analytical power of the models is increased.

Barriers to use: Several factors can discourage application of DHMs. Valid anthropometric accommodation analysis requires expertise, and therefore, tools that support this analysis are often quite complex. R&D is needed to apply knowledge gained in human-computer interaction to the user interfaces and output reports of these tools. Training systems research can also be applied to the design of on-line help, tutorials, and courses for these tools. Tools that help the analyst set up or perform some of the analytical procedures validly may reduce the expertise and training required. These features may include automatic posturing and realistic motions such as reaching. Often, computer-aided design (CAD) files representing the work space, clothing, and/or equipment to be assessed are not available. Creating the files or translating adds considerable time, cost, and opportunity for error. Establishing the basic data requirements for CAD files (e.g., range of motion of moving parts and location of standard human factors reference points such as the seat reference point) into Computer-Aided Engineering tool suites may help. For the military, establishing libraries of digital models tailored for use in human factors analysis may reduce the need to recreate these files from project to project. The U.S. Army requires that models be formally accredited for a specific use (Army Regulation 5-11). Verification processes of tools should be more transparent. An important part of support for accreditation is results of validity studies. Non-proprietary validity studies along with how resulting recommendations for changes in the models were handled are crucial to accreditation. Data and model reuse can encourage economical employment of DHMs. R&D to link models (especially those representing the mental and physical or human factors with systems engineering so that the combination remains valid) should be pursued.

Analytical enhancement: More complex systems and new analytical questions may require greater analytical capability. Analytical capability relating to teams and cooperative work such as more than one person performing a task (e.g., lifting an object) should be researched and incorporated into tools. Anthropometric accommodation analysis has moved to multivariate methods; however, it is still difficult to generate and use a group of boundary figures to determine whether a predetermined population percent (e.g., 90%) is accommodated. If the predetermined percent is not accommodated, the process for determining what percent is accommodated (essentially creating and testing multiple sets of boundary figures) is cost prohibitive. Enhancements of the fidelity of perceptual models (e.g., vision) and modeling of cumulative effects such as repetitive motion have already been mentioned by other panelists, but they are also important to military application of DHMs. Finally, R&D is needed to establish the cost of design trade-offs beyond human performance. Human performance differences must be related to system performance and then life cycle cost to see the true effect of a design change that affects humans. Cost trade-offs may also be presented in terms of medical consequences similar to hearing loss or health hazard prediction models.

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