Applications and Limitations of Today’s Digital Human Models

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ABSTRACT

In several domains, Digital Human Models have matured from pure research topics to software packages which are applicable in today’s life. Success stories can be found for anthropometric and biomechanical models, which have been successfully integrated into the product and production development cycles. Other successful applications can be found for animated, computer-generated figures or human behavior models within computer games. But despite these tremendous and successful developments, other areas of human behavior modeling have not evolved to the same extend and are still similar to early activities in this field, e.g. as they were described by NATO IST-029 on Intelligent Agents in Virtual Reality (2003).

This paper touches the different areas and domains of Digital Human Models and Behavior Models, and their implementations. In an actual proof-of-concept study, human performance models were used to capture, model and simulate a military infantry operation for a prognostic estimation of the effect of additional equipment on military performance. The experiment was carried out cooperatively with the Infantry School of the Armed Forces and showed the general applicability of the approach. On a lower level, anthropometric Digital Human Models can be applied for the technical design of future personal equipments. The results from a validation and verification study carried out at our institute put this into perspective and show the limitations of this approach. Finally, DHMs were used to populate a Virtual Simulation so that detailed case studies could be carried out.

These proof-of-concept studies provided input for a more comprehensive digital human model. The need for interface definition between different types of models was one of the lessons-learned. Some of them are described in this short paper.

1.0 INTRODUCTION

The application field of digital human models (DHMs) is manifold. It reaches from the design of new products and workplaces to applications of computer-generated forces (CGF) in training environments. Therefore, different DHMs can be applied throughout the whole lifecycle of a new system, including design, production, maintenance and training. It is obvious that this broad span cannot be handled by a single DHM only – DHMs are still models and no replica of human operators. Instead, diverse DHMs will be required which all have their special application target. In the following, examples of different types of DHMs will be described. They will be grouped by their main application field: constructive and virtual simulation. Because of the broad functionality and applicability, this separation is rather vague. Several performance or cognitive models are also used to control CGF in virtual simulations and vice versa.

1.1 DHMs in constructive simulation

When talking about DHMs, most people refer to anthropometric and biomechanic human models. These models focus on the inclusion of human body dimensions, movements, and maximum strength into the design of new products, military platforms or personal equipment in early design phases. Recently, they have been well integrated into the industrial system design lifecycle. Some of them have even become part of CAD-packages. With regard to human behaviour, these approaches include biomechanic models and the simulation of simple, goal-directed movements like reaching for targets or gait. For a more comprehensive modeling of human behavior and variability, such models are not sufficient. Instead, they are manually controlled by a human operator. Among others, the most common models are RAMSIS, JACK and SAFEWORK [1, 2, 3]. Recently, AnyBody has been introduced as biokinematic model [4]. Most of the anthropometric models come with a photorealistic appearance and offer functionality for product and workplace design.

Figure.1: Anthropmetric digital human models (sample): RAMSIS, JACK, AnyBody

In addition, human performance models allow for simulating operations of human operators in more complex systems. These models are primarily used for process planning and optimization, e.g. for simulating production systems or maintenance tasks. They include variables for human reliability and performance. Nowadays, special modules for perception, cognition and motor reaction on a psycho-physiological level exist. An example for such models is SAINT: a discrete-event simulation tool that allows the modelling and simulation of procedures and overall performance [5].

Cognitive models, which allow modeling and simulation of human information processing, are primarily research tools and basic frameworks. Most cognitive models are based on a formal analysis and derived from syntactic and semantic rule systems. They can be visualized as a network of probability distribution over neutral states and transitions between the states. Mostly, Bayes rules, e.g., by Hidden Markov Models are used to model the basic cognitive activities. One of these models is the "Atomic Components of Thought – Rational" or ACT-R [6]. It serves as a framework for modeling different tasks in a special programming language.

The latter models approach behavior simulation of a higher level. They model e.g. goal selection and goal generation. With sufficient information and data, it is possible to use them for modeling human decision making during motion planning. In this case, a connection between a high-level performance model and a low-level animation model would make an intelligent model. However, this connection exists only in a very preliminary way in some models, and must still overcome associated technical problems.

1.2 Digital Human Models in Virtual Simulation

The DHMs used in virtual simulation were designed with a background in computer graphics and animation. Therefore, the main focus of these models is photorealism and subjectively perceived realism. With an increasingly growing mass-marked in computer games and in the movies, there has been a tremendous development in this field. Today's models look very realistic, especially when visualized as pictures or within the movies. It is hardly possible to differ between computer-generated and real images.

But simulation of a realistic behaviour has proven difficult and is often implemented off-line by manual programming. This is true for high as well as low-level behaviour levels as e.g. motion sequences. Often, motion-capture of real actors is required. Realistic motion is critical because users are very sensitive to inaccuracies or differences from their anticipated actions. This is because our lifelong experience allows us to notice even small inconsistencies instantly. Furthermore, we often use motion for inferring emotional states, intentions, and goals of the acting entity. Accordingly, slight inaccuracies in motion modelling might therefore easily lead to incorrect inferences about its future actions and goals.

The same is true for modelling of autonomous high-level behaviours, e.g. for problem solving. There are several promising approaches in the area of artificial intelligence (AI) which allow a pseudo-realistic behaviour for a limited problem, but they come to their limits once the problem space is too large. Moreover, users are very sensitive to inaccuracies and notice them instantly. In combination with a virtual simulation this can lead to breaks in presence or negative training.

2.0 EXAMPLES OF DIFFERENT DHMS FOR PERSONAL EQUIPMENT

Conducting dismounted operations places high demands on the soldiers. They have to be optimally equipped and supported by latest state-of-the-art technology. This often requires the development of new functionalities and technologies. Modelling and simulation can be used for an early assessment of the effect of these on overall performance. This can identify potentials and shortcomings of new approaches at a early stage of the lifecycle of new products and, thus, save budget. Further savings are expected if the available models are applied afterwards for applications in training and mission preparation. For our first proof-of-concept a dismounted infantry operation in an urban environment was used as an example. Similar to Concept Development and Experimentation (CD&E), different DHMs were analyzed in order to estimate the potential of such an approach. It gave valuable insights into the applicability of today's DHMs and requirements for their future application.

2.1 Process model of an infantry operation

The operation was a typical military operation in urban terrain, as it is carried out at the training facility Bonnland of the infantry school in Hammelburg, Germany. It included four different tasks: approaching a building, entering the building, fighting room to room and fighting floor to floor. The mission was carried out by two groups of four soldiers. A sergeant was in charge of the two groups. As expected, time for each task varied vastly between subjects. The actions were recorded on video and served as a baseline for the first process model.

At first, a descriptive model of the operation was formulated. It served as basis for the procedural simulation model. For this we used the MicroSaint™ Sharp simulation package. The military action was described as the process, and the connections were defined by the sequence of actions. The simulation revealed that an additional ballistic protection resulted into no extra time required to clear a building. This was surprising because each single actions took longer on its own. The reason for this were shortcomings in teamwork. However, these findings have to be put into perspective because of the limited sample size. But the general usefulness of the approach was shown.

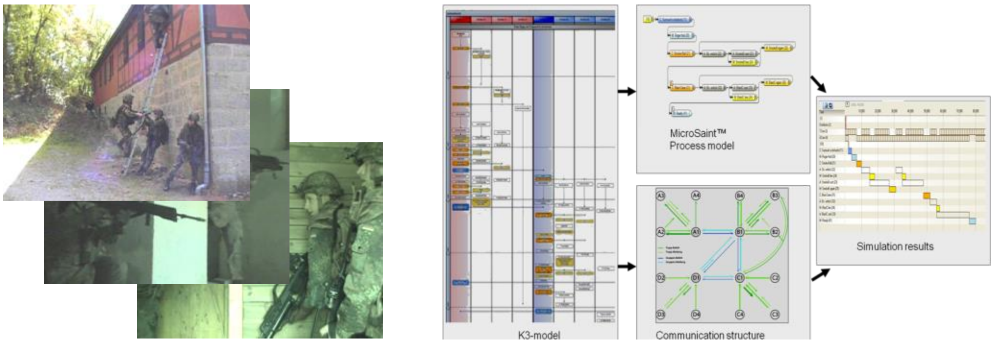

Figure 2: Process of modeling and subsequent simulation of MOUT team operations [7]

2.2 DHM for soldier's personal equipment design

One result of the previous operation simulation was that personal equipment, primarily the ballistic protection, has an impact on human performance in different actions of the operations. This led to insight analysis of the design of ballistic equipment and its effect on individual movement. Different anthropometric DHMs were used to perform this analysis as a second CD&E study [8].

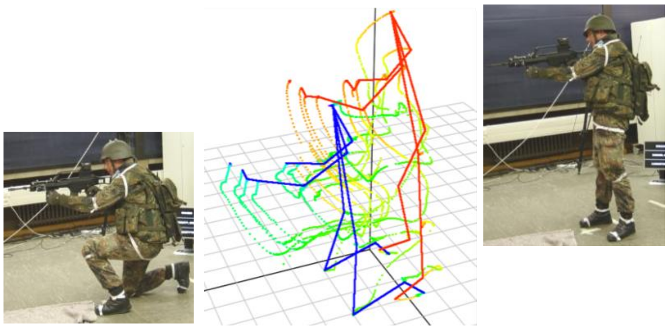

Figure 3 Visualization of different motion trajectories for change of aiming posture

The results show that modern anthropometric DHMs offer functionality for the design of personal equipment to a certain degree. But these results often differ from reality. This may be caused by the DHMs' background in car interior or workplace design and missing studies for the design of personal equipment. Moreover, most DHMs are based on internal skeleton structures and not on surface anthropometry or contour modelling. They cannot be used to design cloths or personal equipment e.g. protection vests or helmets. Today, different activities are carried out to overcome these shortcomings by linking DHMs to such 3D-databases.

2.3 Virtual simulation for detail analysis of selected aspects

Still, detailed insights into special topics of interests require empirical research. By applying virtual simulation, the gap between lab and field studies can be bridged. While the first offer the control of environmental conditions, the second are more application-oriented and realistic. Yet, virtual simulation requires the inclusion of virtual humans in order to enhance realism. But simple static geometric representations are insufficient, because the avatars likely appear like storefront manikins rather than real humans. They would be more appropriately represented as active DHMs [9].

In our study, we used a commercial gaming engine to carry out experiments on special aspects of the design of the user interface of personal IT-equipment. The basic idea was to use the process model as described in section 2.1 as a script for the experiment. However, it was soon clear that this was not possible and so only few phases were selected and modelled manually. The study revealed that virtual simulation, especially commercial gaming engines, is rarely or not connected to process models or anthropometric human models. Instead, they offer developing kits (e.g. sandboxes) as their own framework. For a closer inclusion it would make sense to foster the exchange of these technologies with other types of human behaviour models.

3.0 CONCLUSIONS: REQUIREMENT FOR INTERFACE AND INTEROPERABILITY BETWEEN DHMS

There are many different human models available which offer different functionalities for different applications in the military domain. Our proof-of-concept showed that they can be well applied and that they have promising benefits when estimating the effect of new technology on military performance. It was also discovered that a single, comprehensive model is not (and will not be) available. Instead, individual types of models exist already for different purposes. However, they are not connected to each other and there are very few interfaces between them today. This leads to a time- and labor-intensive restart of the design work for each model. Instead, it would make sense to define standards for interfaces between the different models.

They should address the combination of different human behaviour models during the system design lifecycle. A process model can be used to model the operational background and to perform a first analysis of functionality gaps. Detailed models, e.g. anthropometric models, can be applied in order to test the geometric design. In parallel, cognitive models can be used to analyze the information presentation und information interaction. Finally, virtual simulation models can be applied to carry out detailed analyses and evaluate the final design. They can also be used for education and training.

The interfaces have to address: processes and resources of the operational background (i.e. organization ergonomics), geometric design (i.e. technical ergonomics) and information design (i.e. cognitive ergonomics). In accordance to the ongoing work of the Technical Committee on Human Simulation and Virtual Reality (TC HSVE) of the International Ergonomic Association (IEA) in the civil domain, it is concluded to work on software interfaces between different human and behavior models in order to work towards a comprehensive model. In this way, benefits of the different models which are already available can be considered and redundant work can be prevented.

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