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RAMSIS - DIGITAL HUMAN MODELING FOR OPTIMIZED SAFETY AND SURVIVABILITY OF THE WARFIGHTER

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ABSTRACT

The study describes the development of a plug-in module of the realistic 3D Digital Human Modeling (DHM) tool RAMSIS that is used to optimize product development of military vehicle systems. The use of DHM in product development has been established for years. DHM for the development of military vehicles requires not only the representation of the vehicle occupants, but also the representation of equipment and simulation of the impact of such equipment on the Warfighter. To simulate occupants in military vehicles, whether land or air based, realistically, equipment must become an integral part of the extended human model. Simply attaching CAD-geometry to one manikin's element is not sufficient. Equipment size needs to be scalable with respect to anthropometry, impact on joint mobility needs to be considered with respect to anatomy. Those aspects must be integrated in posture prediction algorithms to generate objective, reliable and reproducible results to help design engineers making better products. Products that are safe, comfortable and appropriate for the Warfighter.

INTRODUCTION

One major challenge in the design of military vehicles is limited space for occupants. This often results in poor ergonomics. In consequence, the products often do not offer optimal conditions for the Warfighter to accomplish required physical tasks, foster effective procedures and work patterns. Military products must be safe, comfortable and appropriate for the Soldier to best support the safety and performance of the troops.

To be more efficient in the design and development process, manufacturers must perform virtual testing and packaging studies, including human representation in CAD in order to optimize the layout of military vehicles in the early design stages. The top priority is the safety and survivability of the Warfighter in a tactical vehicle, whether land-based or air.

PROBLEM

Military Standard MIL-STD-1472G refers to the compatibility with users and the accommodation of the user population in military equipment, that "…equipment shall assure that suitably clothed and suitably equipped user personnel within the central 90 percent of the anticipated user population for body dimensions for three-dimensional design elements (such as crew workspace) are accommodated" [1]. 3D Digital Human Modeling (DHM) is an adequate tool to ensure that those types of design standards can be considered from the earliest design stage towards the final product. RAMSIS is a 3D DHM Software. RAMSIS is an acronym in German for: "Computer Aided Anthropological Mathematical System for Occupant Simulation" [2]. It is a DHM that represents the human body in a virtual 3D CAD environment. RAMSIS is the leading DHM for ergonomic simulation in vehicle design. It has become a de-facto standard for occupant packaging and ergonomic layout in the automotive industry. The software was developed in cooperation of the German automotive industry, Tecmath in Kaiserslautern, Germany (now Human Solutions) and the Institute of Ergonomics (Lehrstuhl für Ergonomie, LfE) at the University of Technology Munich (Technische Universität München) [3].

Their goal was to overcome the insufficiency of the existing tools, e.g. the widely used two dimensional SAE J826 template, to improve consideration of human properties and proportions in vehicle design beyond legal requirements. RAMSIS is now used by almost all car manufacturers globally.

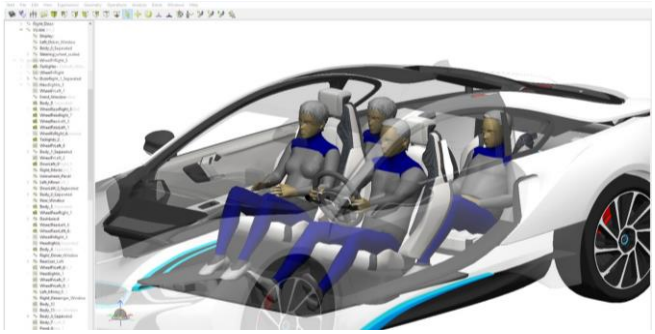

Figure 1: RAMSIS Software can be used e.g. for occupant packaging studies

Over time, additional RAMSIS modules for application in industrial vehicle design, aircraft and industrial engineering were successfully introduced into the market. The software provides engineers with a detailed CAD representation of the human body that can be positioned and animated in a virtual space to simulate the end-user. It enables design engineers and Human Factors specialists to perform extensive ergonomic analyses in the early stages of the product development process using only rudimentary CAD data, thereby preventing costly follow-up improvements.

The quality of a DHM depends on the quality of the input anthropometric database for body measurements and proportions. A major benefit of the RAMSIS DHM Software is that the manikin's body measures are based on the most up-to-date anthropometric databases. This includes publicly available data as well as Human Solutions' proprietary databases, like Size NorthAmerica – the new North American Anthropometric Survey (Size NA). Size NA is a size survey of 18,000 people all over the United States and Canada using high-tech 3D body scanning technology to capture and extract body measurements automatically [4].

Another main benefit of the RAMSIS Software is the automatic posture calculation which enables the user to constrain the DHM within the CAD environment and calculate the most probable posture within the given geometry. The probability calculation is based on different

posture models. This generates reliable, objective, and reproducible postures and positions as a result. Compared to other DHM Software this approach enables a user independent positioning of the manikin. The outcome of manual DHM posture modeling is always subjective.

To simulate occupants, e.g. military personnel, realistically in a vehicle, clothing, shoes and safety equipment need to be considered, as they substantially impact the seating position and body posture. In general, it is possible to attach single CAD geometry elements to a manikin. Within RAMSIS it is also possible to create so-called reference points on these geometrical elements, which can be considered within the automatic posture calculation. But the amount of equipment that can be attached is limited, objects are attached as rigid CAD parts to only one single body segment, reference points refer to the manikin's skinpoints of the related body segment (fig. 2).

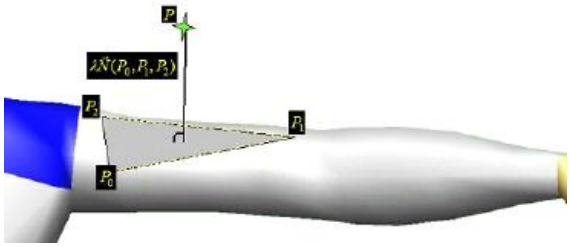

Figure 2: Definition of a reference point referred to the upper arm of a RAMSIS manikin

To simulate fully encumbered Soldiers, it is necessary to enhance the DHM for a more realistic simulation and better results, making equipment an integral part of the DHM.

Methods

The herein described study was conducted in cooperation with the German Bundeswehr (Technical Center for Land-Based Vehicle Systems, Engineer and General Field Equipment).

It describes the development of a new RAMSIS plug-in module "RAMSIS Defense" to simulate occupants realistically, with equipment that becomes an integral part of the Digital Human. Equipment attributes like size and impact on joint mobility need to be considered with respect to anatomy and anthropometry and must be integrated in the RAMSIS posture prediction algorithm. The data for the development of the module was collected with high-tech 3D body scanners (VITUS**bodyscan** by Vitronic GmbH, Wiesbaden, Germany) and cinematographic analysis of joint movement. The VITUS**bodyscan** body scanner measures subjects with at least 1 mm accuracy, it also complies with the DIN EN ISO 20685 international standard [5]. This scanner is based on a completely new, highly accurate calibration procedure and utilizes advanced hardware components. Color is also captured to scan garment texture. The advanced scanning volume of the VITUS**bodyscan** also allows a greater flexibility in capturing subjects in different poses. The scanner has the ability to create an exact 360° image of the subject [6].

Soldiers of the German Bundeswehr were scanned in different configurations: lightly dressed, with light and full protective gear in order to determine the position of the protective gear with respect to the body and changes in body posture. Effects on joint mobility were carried out in a separate experiment where soldiers had to perform different motion tasks. Subjects were asked to bend specific joints to a maximum range of motion (ROM) and a subjective, comfortable ROM with and without equipment. The data was captured with cinematographic methods, results were analyzed and processed and probability distributions for joint angles were calculated. The limited ROM is calculated as the minimal interval over all ROMs, caused by the different equipment objects.

$$ARange(\alpha) = [\max\{\alpha_{min,object_i}\}, \min\{\alpha_{msx,object_i}\}]_{\ i=1..n} \quad (1)$$

The impact of the limited ROM was implemented by accumulating probability functions for individual DoF. The following

picture gives a schematic overview of the methods used in this study (fig. 3).

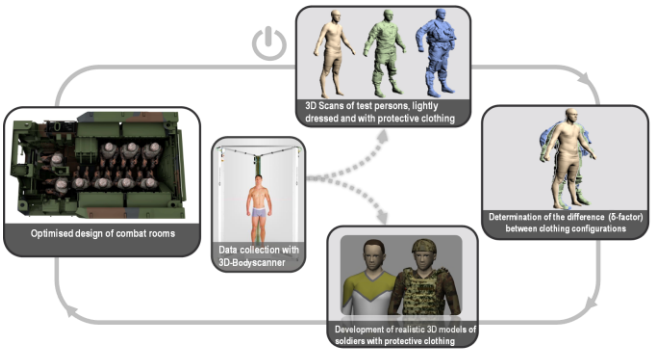

Figure 3: Schematic description of the methods used to develop the DHM

Results

The results of the study were integrated into a new RAMSIS module for the simulation of 3D DHM with equipment that becomes an integral part of the model (fig. 4).

Figure 4: RAMSIS DHM without and with military equipment as integral part or the digital model.

The following aspects have been considered for equipment object items and the DHM. Figure 5 gives an overview of included elements, element properties, interrelations and interdependencies:

- Object geometry
- Attachment and animation parameters
- Dependencies between model and equipment and equipment itself
- Impact on model structure and characteristics
- Effects on posture models and automatic posture calculation
- Impact on additional specific parameters, e.g. seat-belt simulation and others.

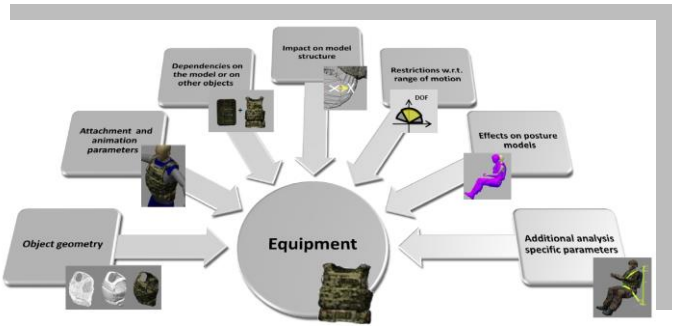

Figure 5: To make equipment and integral part of the DHM various aspects need to be considered. The illustration shows the complexity of this project

Specific equipment objects are provided as an equipment library and can be put onto the DHM by double-clicking on an equipment icon. Attachment position and animation parameters refer to the scanning study mentioned above. Dependencies between the human model and the equipment, as well as the equipment itself, were implemented. This allows that objects are automatically scaled when the manikin's anthropometry changes or prevents from redundancies, as for example attaching multiple helmets onto one single manikin. Furthermore, the equipment objects influence directly the characteristics of the DHM: position of the H-Point of the DHM and the ROM as well as Degrees of Freedom (DoF) of the model joints. Joint limits can be displayed and evaluated for each joint (fig. 6).

Figure 6: Manikin with attached boot from the equipment library to the left foot. Table with information on the limited ROM for flexion/ extension and pronation/ supination of the left ankle is displayed.

One unique advantage of the DHM RAMSIS is the automatic posture calculation, based on posture models that are scientifically evaluated [7]. The combination of multiplying object specific distributions, including a final resampling and scaling, resulted in a probability function that represents the most probable body angles for the affected body joints. Furthermore, the attached equipment can change the location of the manikin's H-Point offset (see equation 2). An H-point simulates the offset between hip joint and seating reference point. "Automotive vehicle packages are mainly analyzed using the H-Point approach, which has been validated to properly model the human-seat interaction in posture predictions (Loczi 1999, Seidl 2006)" [8].

$$Offset_{H-Point} = max\{Offset_{object_i}\}_{i=1..n} \quad (2)$$

Individual object kinematics, depending on the attachment method, were considered by the software. Rigid objects are attached to only one body element (e.g. helmet), rigid objects that touch the body on large surface (e.g. back pack) or flexible objects like tissue are attached to the manikin skin over multiple body segments (e.g. pants). The following multi-layer picture displays the flexibility of the garment (fig. 7).

Figure 7: Display of the flexibility simulation of clothing and equipment

Conclusion

The use of the RAMSIS Defense Module was successfully tested by the German Bundeswehr and Australian Defense services. And it will be publicly available as a plug-in module for all RAMSIS NextGen versions in 2018. It is the adequate tool for designers, engineers, and Human Factors specialists, working on optimization of tactical vehicles, land or air based, with the objective to protect the Warfighter and optimize overall systems performance with respect to military standards.

The use of DHM in design & development is necessary to ensure an ergonomic layout, evaluation of body clearance and safety of vehicle occupants and other analyses. The integration of this technology in the early design phase reduces time and cost significantly. This has been shown in use-cases in the automotive industry [3]. Furthermore, the new RAMSIS Module can help in the selection of suppliers for material procurement of all armed forces and law enforcement institutions.

As the functionality of the module is not only restricted to military equipment, the module will also find high demand in the design of industrial vehicles. This holds true for commercial vehicles, such as trucks and agricultural machinery, but also for All Terrain Vehicles (ATV) and all kinds of Side-by-Sides (SxS). The demand for ATVs and SxS is constantly growing [9]. Helmets and protective gear are required to operate those vehicles safely. The evaluation of body clearance to structural parts of the vehicle is crucial. The RAMSIS Defense Module is the appropriate tool to check those critical design aspects.

Further development for the RAMSIS Module will include an extension of the object library, parametrization and additional representations. The new features described in this paper will also be included in other RAMSIS Modules as e.g. the Seatbelt Design Module in order to consider clothing and equipment for the calculation of a CAD seatbelt routing and appropriate fit over shoulder and sternum. Another feature, an extended collision detection that visualizes collisions between manikin, equipment and CAD environment, will be available. Approximation of equipment objects will be calculated.

The new RAMSIS plug-in “RAMSIS Defense” enables an occupant centric approach for improved safety, comfort, reliability and performance of the troops. The application of this anthropometric DHM Software will further ensure the optimized safety and survivability of the Warfighter, fulfilling our top priority.

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