Applications of Digital Human Modeling in Industry

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Abstract. This paper represents current and probable applications of Digital Human Modeling (DHM) in different industries. Three real-world challenges, Cummins Inc. (New Product Launches), NASA (Ground Operations), Purdue University (DHM in Curriculum), are investigated for current/probable benefits of DHM. Direct contacts with company representatives and academic faculty were established to understand the current challenges and probable demands of tasks/operations in industry where DHM tools can be utilized. Dassault Systemes' CATIA V5 PLM solution package and UGS Tecnomatix JACK DHM software was utilized to offer a resolution for industrial (Cummins Inc. and NASA) challenges and a software manual (JACK) is developed to enhance the engineering curriculum at Purdue University. The results indicated that DHM tools have potential to improve the product development challenges and provides control of the entire process of designing and analyzing a product before it's ever launched. DHM in engineering curriculum would also increase the integration/adaptation of DHM tools in industry.

Keywords: Digital Human Modeling (DHM), Digital Manufacturing, Computer Aided Design (CAD), Product Development, Human Factors and Ergonomics, Product Lifecycle Management, Engineering Design, Motion Capture.

1 Introduction

Many industries have the same challenges where the human element is not being effectively considered in the early stages of the design, assembly, and maintenance of products. However the use of DHM tools can increase the quality by minimizing the redundant changes and improve safety of products by eliminating ergonomics related problems [1].

A possible software solution available in the industry to address the challenges of improving product development and controlling process of product design and analysis is to utilize the integration between DHM and PLM solution packages. DHM uses digital humans as representations of the workers inserted into a simulation or virtual environment to facilitate the prediction of performance and/or safety. Also, it includes visualizations of the human with the math and science in the background [2].

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DHM helps organizations design safer and efficient products while optimizing the productivity and cost. Applications that include DHM have the potential to enable engineers to incorporate ergonomics and human factors engineering principles earlier in the design process [3]. An example at Ford Motor Co. involved the UGS Tecnomatix Jack human simulation solution to evaluate ergonomics and worker safety in installing a new satellite digital antenna radio system. This analysis occurred early, at the product design review stage. This reduced the late design modification efforts and helped assess performance and ergonomics based problems prior to prototyping [1].

UGS Tecnomatix JACK [4], one specific piece of the PLM software, is a part of a UGS Product Life-cycle Management (PLM) product solution package, which has been used to prevent human factors and ergonomics related deficiencies in product development. This provides benefits such as a shorter design time, reduction in redundant design changes, lower development costs, improved quality, increased productivity, enhanced safety, and heightened morale. JACK focuses on improving the design of a particular product in the ergonomics and human factors aspects by using Digital Human Modeling [4].

2 Studied Applications of Digital Human Modeling

This paper investigates different application areas of DHM in industry. Three real-world challenges, Cummins Inc. - New Product Launches (IE431 Senior Design Project), NASA - Ground Operations (IE486 Semester Project), Purdue University - DHM in Curriculum (IE499 Honors Program Research), are investigated for current/probable benefits of DHM. Direct contacts with company representatives and academic faculty were established to understand the current challenges and probable demands of tasks/operations in industry where DHM tools can be utilized. Dassault Systemes' CATIA V5 PLM [5] solution package and UGS Tecnomatix JACK DHM software was probed to offer an inclusive resolution for industrial (Cummins Inc. and NASA) challenges and a software manual (JACK) is developed to enhance the engineering curriculum at Purdue University.

2.1 Cummins Inc. – New Product Launches

Cummins Inc., headquartered in Columbus, Indiana, is a corporation of complementary business units that design, manufacture, distribute and service engines and related technologies, including fuel systems, controls, air handling, filtration, emission solutions and electrical power generation systems. Cummins serves customers in more than 160 countries and reported net income of $550 million on sales of $9.9 billion in 2005 [6].

Approximately every two years the design of the engine is modified to comply with EPA emission regulations as well as other issues relating to customer requirements. These modifications, although usually minor with few visible differences, sometimes require drastic changes in the engine assembly process which poses the problem of retraining more than 600 people. Training this large of a population is challenging due to the constant production requirements which demand that lines do not shut down for training activities. Historically, training may take as long as 6 months, which inhibits the Cummins Inc.'s ability to deliver final products to their customers. Cummins Inc. has requested assistance to review their current training standards and procedures to help to improve the transition from engineering design to production and reduce the cycle time [7].

In order to find the reasons of long training period, direct contact with the training manager, engineers and assembly line workers was established. Also, current training methods were evaluated and compared to other organizations [8,9]. It was found that the current training system is appropriate for the organization. However the real problem lies with the constant design changes resulting primarily from customer feedback. The rerouting of tubing and too much vibration in the test trucks that have new engines in them are examples of required changes due to customer demands. When problems arise there is an immediate effort to fix the problems before the engine is launched which sends large amounts of changes to the assembly line after the line has already been set up and workers trained on the existing engines. For each design change, the training cycle must be redone and many workers who were already trained on the previous process must be retrained on a different process. The only shift to see these multiple design revisions is the first shift since training on the other shifts only happens once the first shift is fully trained. As a result, on the most recent new engine transition the first shift took six noncontiguous months to train compared with two weeks for the second and third shifts. This disparity is due in large part from the first shift having to experience multiple assembly task revisions. Better integration is needed between design, manufacturing and training departments. The team also takes into account worker interactions on process steps by using their EASE database during assembly which is a single source of standard times to perform particular tasks. Although relatively accurate, EASE task times sometimes do not match up with reality, a problem that may not arise until engines are being produced on the assembly line while training is taking place. In this regard, a digital work simulation with an up-to-date ergonomics data base is needed to improve the assembly line training. [7] (see Fig.1.)

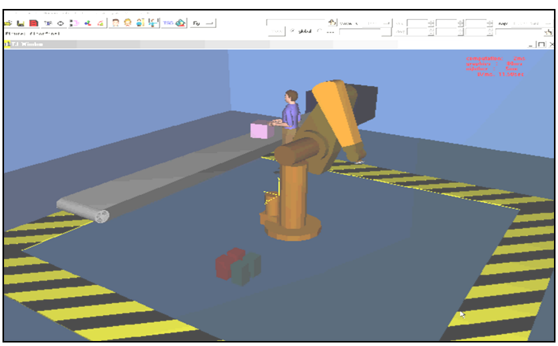

Fig. 1. Assembly Line and virtual worker

2.2 NASA – Ground Operations

In September 2005, NASA [10,11] unveiled its new plan, which includes the NASA's next spaceship, Crew Exploration Vehicle (CEV), Orion [12]. Orion is a manned space craft, which is currently under development, being designed to carry astronauts to the moon and back as well as having future goals to reach Mars [13,14].

One of the biggest challenges in Orion program faces is the ability to carry and shift current operations, skills and expertise to a new technology system. Furthermore, given the value of the expertise that veteran technicians have, many of which will be retiring within a few years time, it is of critical importance to catch this knowledge to pass it along the newer generation of NASA technicians [15].

The proposed approach in this project was to divide each critical knowledge area into two categories depending on the demands of each sub-task: knowledge and methodology. "Knowledge" category was defined to be all of the concepts and background information that technicians need to know in order to successfully perform each task. The other category, labeled as "methodology", includes the entire practical and hands-on experience that is needed to perform a specific task within mission preparation and pre-launch operations. In other words, "knowledge" describes the abstract concepts while "methodology" focuses on the specific practical applications of these concepts [16].

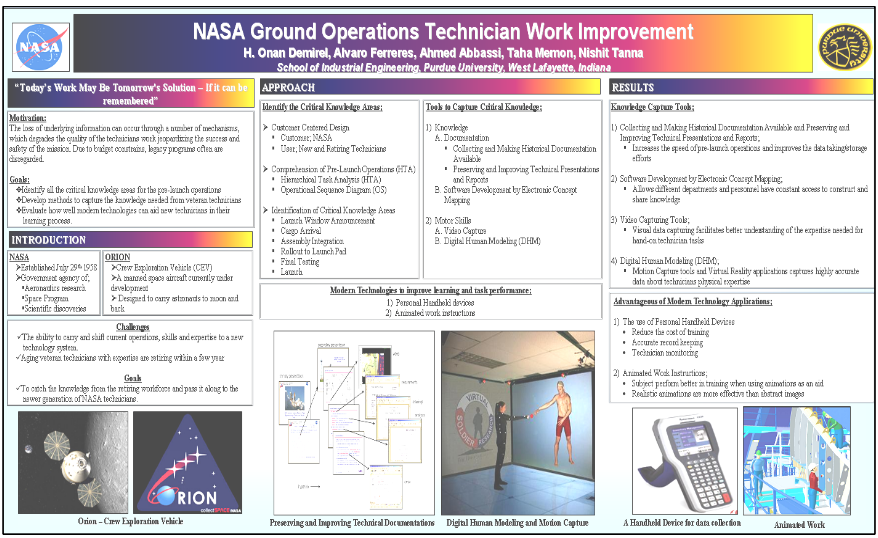

Fig. 2. NASA – Ground Operations and DHM

After capturing all necessary knowledge to cover the technician critical areas, the next step is to capture all the hands-on expertise that is used during the pre-launch operations of any given NASA mission [17,18]. To do so, a process consisting of two parts was developed: The first part consists of capturing simple tasks by means of video [19,20], while the second part concentrates on very critical aspects of the pre launch operations. DHM was regarded as a way to capture all of the detailed motions as well as to correct any bad practices during the process so they are not passed along to the next generation [16]. Motion Capture tools and digital simulation of workers are proposed as possible solutions for both knowledge capture and further training of new workers. (see Fig.2.) It is unlikely that all of the information exposed to the new technicians through the formal class room as well as the case studies will be remembered in full [15,21]. This is one of the reasons why DHM is proposed as one of the new/alternative knowledge capture and training technologies in this project.

2.3 Purdue University – DHM Curriculum

The growing interest in human-centered design practices brought the importance of human safety, usability and performance. This motivates engineers to understand the

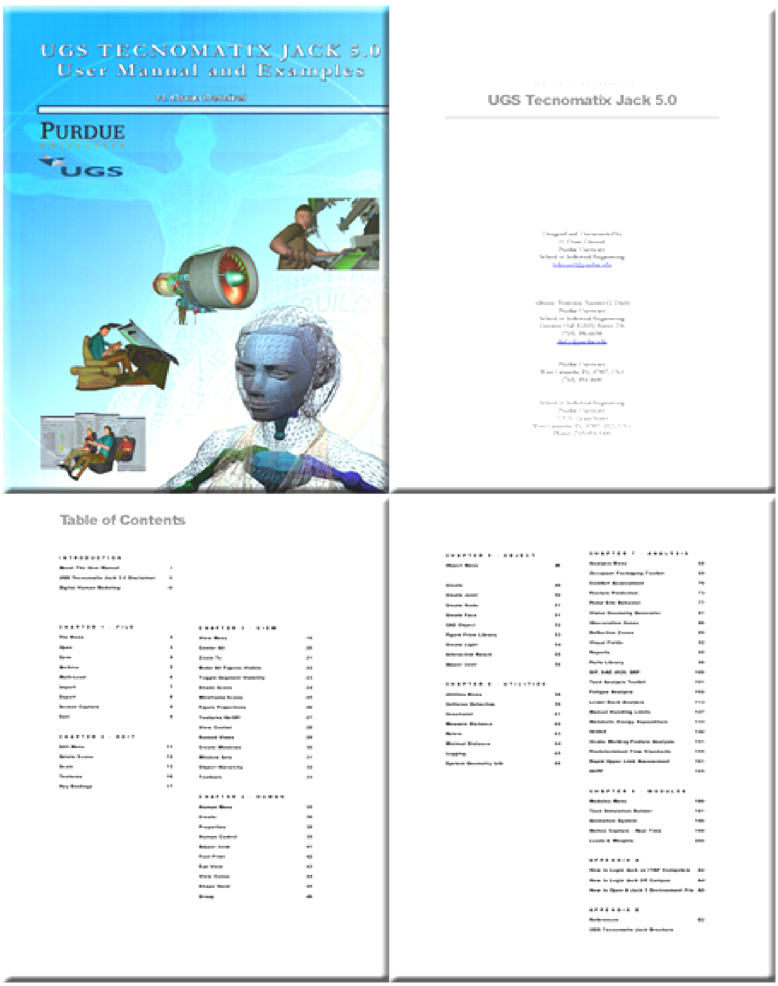

Fig. 3. Jack Software Manual developed at Purdue

human values and needs to allow them to design products, services and experiences that people truly value as individuals and as a culture [22]. Also, engineering problem-solving is not only a technical challenge; it also lies on societal and human side of engineering [23]. Industrial leaders are seeking students with research based teaching and learning experience, as well as strong communication and team based working skills. These challenges in engineering practice require sculpting the engineering curriculum with up-to-date technological tools and knowledge to enhance the technical, social and intellectual capabilities of students to be more creative to answer complex real-life engineering problems. Also continuing to update the technical skills, expertise and knowledge with latest scientific and technological developments will ensure the future competitiveness and success of engineers [23]. In this regard, comprehensive JACK software manual (see Fig.3.) is developed as a research work in Purdue University to offer students a background support in area of DHM, and applied ergonomics. The purpose of this manual is to be a reference to someone using DHM software and to help the individuals' ongoing professional development. At Purdue University three courses (IE 590D Applied Ergonomics, IE 656 DHM Research Seminar, and IE 486 Work Analysis & Design II) are available to provide students an up-to-date engineering curriculum with applied DHM. In addition, Purdue Envision Center and Purdue Discovery Park Center of Advanced Manufacturing have additional software and hardware available for further interest in DHM research and development.

3 Results

After three different real-world challenges (Cummins Inc., NASA, and Purdue University) are analyzed, a common answer for both challenges is highlighted. DHM and its integration with PLM have potential to improve the product development challenges and provide control of the entire process of designing and analyzing a product before it's ever launched. Proposing a DHM curriculum with a ready to use software package would also improve/update the engineering quality and provide a unique educational experience for students.

In the Cummins Inc. study, a PLM-based JACK software could be a good solution for industries where constant design changes are slowing the expected training time and speed of production due to customer and ergonomics based modification needs. Before launching a new product, human factors and ergonomics components of JACK software can be utilized in the design department by considering the needs of workers and customers. Moreover, simulation toolkits of JACK software may help the training teams to visually train their workers on the job site. Also, the PLM integration will keep all departments (design, manufacturing, training, management, etc.) in contact. This could improve the quality of the final product and customer satisfaction. In Cummins' specific training improvement challenge, training leaders can see any changes done by the design department before having their training plans. This integration will benefit the company by lowering training costs and the training time.

In order to capture specific physical task attributes of a technician in NASA's Prelaunch Operations, DHM tools can be implemented as the last step to capture and correct any awkward physical work habits (wrong postures, excessive lifting…).The technician's physical expertise can be captured in detailed through motion capture sensors. Furthermore, the usage of certain body functions (hand dexterity, reach and move motions, etc.) can be recorded and stored to be later corrected before they are passed along. Ergonomics analyses of new working environment, tools and transportation vehicles within NASA prelaunch facilities can be accomplished as well.

In order to meet the objectives of the new DHM curriculum, software manual for JACK is developed and proposed for students in IE486 Work Analysis and Design II [24]. The software manual is intended for use in introducing students to the operation and applications of DHM and Computer-Aided Design (CAD) systems. The purpose of this manual is to be a reference to someone using the JACK software. The user manual covers JACK's tools and menu commands. It explains each tool and menu command in details with pictorial examples. It also covers frequently used industrial applications and demonstrates those in details through step by step method.

4 Conclusion

Use of DHM applications and integration of those with PLM solutions have noticeable advantage in product development. Number of design changes and cost of rapid prototyping can be optimized by DHM and PLM integration. Another advantage of UGS Jack software is its capability of integration with UGS PLM packages, which allows engineers to have control of the entire process of designing and analyzing a product before it's ever launched. It also provides real cost savings to the industry by integrating different departments (design, management, marketing, manufacturing, training, etc.) within a company. This cross-departmental integration increases the quality and the speed of information flow. A leading PLM consultancy, CIMdata, concluded: On average, organizations using digital manufacturing technologies can reduce lead time to market by 30%, the number of design changes by 65% and time spent in the manufacturing planning process by 40%. Production throughput can be increased by 15% and overall production costs can be cut by 13%. [25].

The educational goal of this work is to develop an enhanced engineering curriculum, building on human factors and ergonomics science fundamentals, in which students benefit from the latest technology tools and knowledge. This collaborative research & development teaching and learning approach would increase the engineering problem solving capabilities of the students and will also allow students to interact in interdisciplinary engineering industrial research projects. It is authors' opinion that an engineering curriculum supported with DHM education would increase the integration and adaptation DHM in industry.

5 Future Work

Simulation tools help engineers and scientists to replicate the operation of complex systems by using computer software. Advanced computer integration in engineering is necessary for understanding the complex systems ranging from building jet engines to simulation of earthquake shocks. DHM software facilitates this integration possible and provides solution for complex engineering design and analysis problems. Advancements in computer technology will increase the engineering design and analysis capabilities, improve the product ergonomics and enable engineers to control of human-machine virtual reality applications.

Despite its advantageous, further research and development is necessary to develop graphically advanced, virtually interactive DHM models which include cognitive and physiological aspects of human and working environment. Graphically advanced (more realistic) DHM models will allow engineers to work with virtual reality environments to gain control in product design in earlier stages of product development. Also advanced computational processing capabilities will make it possible to develop advanced mathematical models for DHM applications. A future software development which includes full-body finite human models may take the place of crash test bodies in transportation design and in military applications. This will enable engineers to incorporate advanced human-object and object-object simulations before physical prototyping. Also, advance simulation capabilities with easy micro and macro motion control capacity is required to allow engineers to test robotic devices which are controlled by a human operator.

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